DOT/FAA/ND - 95/4

Research and Development - Communications, Navigation, and Surveillance
Washington DC 20591

Situational Awareness for Safety (SAS) Management Plan

Mark Cato

Prepared for:
FAA/AND-610 - General Aviation and Vertical Flight Program Office
800 Independence Ave SW
Washington DC

By:
Crown Communications
1850 K Street NW
Washington DC 20006

March 1, 1995

Final Report

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

U.S. Department of Transportation
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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/ND-95/4		

4. Title and Subtitle	5. Report Date
Situational Awareness for Safety (SAS) Management Plan	March 1, 1995
	6. Performing Organization No.
7. Author (s)	8. Performing Organization Report No.
Mark Cato	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Crown Communications 1850 K Street NW Suite 1200 Washington DC 20006	11. Contract or Grant No. DTFA01-94-Y-01041
12. Sponsoring Agency Name and Address	13. Type Report and Period Covered
Federal Aviation Administration General Aviation and Vertical Flight Program Office (AND-610)	Final Report
	14. Sponsoring Agency Code AND-610

15. Supplementary Notes

16. Abstract

The Federal Aviation Administration (FAA), with the advice and assistance of the aviation community, developed the Situational Awareness for Safety (SAS) concept. SAS, a cockpit-oriented operational concept, emphasizes flight standards and procedural applications based on advances in human factors, cognitive pilot decision making, computer and display technology, advances in precision navigation, data link, and aviation weather systems. Simply put, SAS is the exchange and use of GPS position, terrain, weather, and other information, effectively displayed to pilots, dispatchers, and controllers, to create an environment promoting more efficient, safe, and free use of airspace. This information exchange will contribute to an environment that will facilitate implementation of the emerging "free flight" concept.

The Management Plan describes the SAS initiative in some detail and provides the framework for the development of guidance, standards, and procedures that will provide standardized hardware and software for SAS implementation. The activities and coordination measures established herein will be used to develop standards for the manufacture of equipment, operational procedures, and validation of the SAS concept. Successful execution of this SAS Management Plan requires frequent review of its contents to ensure that SAS development matures in a consistent direction that reflects changes in technology, concepts of operation, and changing user requirements.

17. Key Words	18. Distribution Statement
Situational Awareness for Safety (SAS), Data link, Automatic Dependent Surveillance-Broadcast (ADS-B), Global Positioning System (GPS), "Free Flight", Flight Management System (FMS)	This document is available to the U.S. Public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	102	

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EXECUTIVE SUMMARY

Advances in aeronautical data link, computer and display-related technology, coupled with national and international acceptance of the NAVSTAR Global Positioning System (GPS) have created an environment rich in modern tools that can be applied to age-old airspace management and pilotage problems.

The Federal Aviation Administration (FAA), with the advice and assistance of the aviation community, developed the Situational Awareness for Safety (SAS) concept. SAS, **a cockpit-oriented operational concept,** emphasizes flight standards and procedural applications based on advances in human factors, cognitive pilot decision making, computer and display technology, advances in precision navigation, data link, and aviation weather systems. Simply put, SAS is the exchange and use of GPS position, terrain, weather, and other information, effectively displayed to pilots, dispatchers, and controllers, to create an environment promoting more efficient, safe, and free use of airspace. This information exchange will contribute to an environment that will facilitate implementation of the emerging "free flight" concept.

For the SAS concept to be successful, from the onset a strategy based on four pivotal imperatives must be followed:

1. Compatible airborne and ground equipment must be developed that maximizes human factors technology while providing increased capacity, efficiency, and safety.

2. SAS design, development, and implementation requires the full participation of all appropriate FAA elements.

3. The user community must be involved as full participants in the SAS process.

4. SAS development and implementation must be harmonized with ICAO.

This Management Plan describes the SAS initiative in some detail, and provides the framework for the development of guidance, standards, and procedures that will provide standardized hardware and software for SAS implementation. The activities and coordination measures established herein will be used to develop standards for the manufacture of equipment, operational procedures, and validation of the SAS concept. Successful execution of this Management Plan requires frequent review of its contents to ensure that SAS development matures in a consistent direction that reflects changes in technology, concepts of operation, and changing user requirements.

1.0 INTRODUCTION

Satellite technology has achieved nearly universal national and international acceptance as the basis for future communication, navigation, and surveillance systems. Major programs are in effect to implement this technology as soon as possible in the National Airspace System (NAS). To date, most of these applications are targeted for the air carrier arena. However, this same technology holds great potential for **all** airspace users.

To fully realize the combined potential of GPS and data link technologies in the context of enhanced situational awareness, specific operational concepts, policies, requirements, and procedures must be developed, validated and published. One of the initial concepts identified to meet this need is called Situational Awareness for Safety (SAS).

SAS is a cockpit-oriented operational concept emphasizing flight standards and procedural applications based on advances in human factors, psychology (i.e., cognitive pilot decision making), computer and display technology, precision navigation (i.e., GPS), data link, and advances in collecting and disseminating textual and graphical aviation weather. SAS is intended to meet the near-term safety and efficiency needs of both civil and military airspace users within the framework of compatible air traffic services. The air traffic tie-in is based, to a large extent, on a synergistic tie-in with an aircraft's GPS based ADS-B message. (The term "ADS-B" refers to a broadcast form of ICAO's automatic dependent surveillance message format.)

The SAS concept, by providing increased cockpit situational awareness via use of object-oriented, user friendly display(s) coupled with the presentation of textual and graphical data, offers the possibility of making a profound impact on aviation safety, capacity, and efficiency. (In this context, enhanced cockpit situational awareness includes increased knowledge as to the "status" condition of the aircraft as well as enhanced knowledge about the aircraft's external environment.)

Through SAS, advanced flight and information management integration technologies and technical standards like the Tactical Conflict Probe (TCP) for GPS ADS-B will safely enable "free flight" in the GPS era by suitably equipped airspace users.

Currently in the initial stage, the SAS project offers the potential for a positive impact on aviation safety and system capacity and efficiency. SAS will provide enhanced cockpit situational awareness for all aircraft through low cost application of new techniques in information delivery and display.

This Management Plan describes the SAS project, as it is presently envisioned, with concomitant projects and activities designed to provide project guidance and focused on development of SAS and related products for the aviation community. It is meant to be a living, dynamic document, with periodic revisions based on changing operational requirements and input from users, service providers, and their supporting labor and

professional organizations. As such, it represents an iterative process to continuously identify and define objectives that will result in the development of guidance for manufacturers of the avionics equipment needed to realize SAS objectives.

1.1 Purpose

SAS initiatives will provide a forum and "process" for the development of technical and operational standards, requirements, guidelines, procedures, and processes necessary to implement SAS concepts and to assist in the development of incentive programs to encourage maximum utilization of SAS equipment and capabilities. (See Figure 1-1)

1.2 SAS Concept

This document deals primarily with enhanced situational awareness from a cockpit perspective. However, the SAS concept also presents significant opportunity for advancements in dispatcher's and air traffic controller's situational awareness. To realize this full SAS potential, both ground and air systems must be carefully coordinated and integrated to complement each other in an advanced Communications, Navigation, and Surveillance System (CNS) environment.

Within a compatible Air Traffic Management (ATM) environment, SAS derived technologies facilitate capabilities such as: redispatch (including coordination of alternate airport diversions), passing maneuvers, station keeping (leading to reduced separation minima), precision ocean track entry and exit, timely and accurate textual and graphical weather presentations, on-board surveillance of nearby traffic, surface movement situational awareness, and wake-vortex visualization. There are 59 SAS candidate applications that have been identified to date; see Appendix 2, "List of Candidate SAS Applications," for a complete listing.

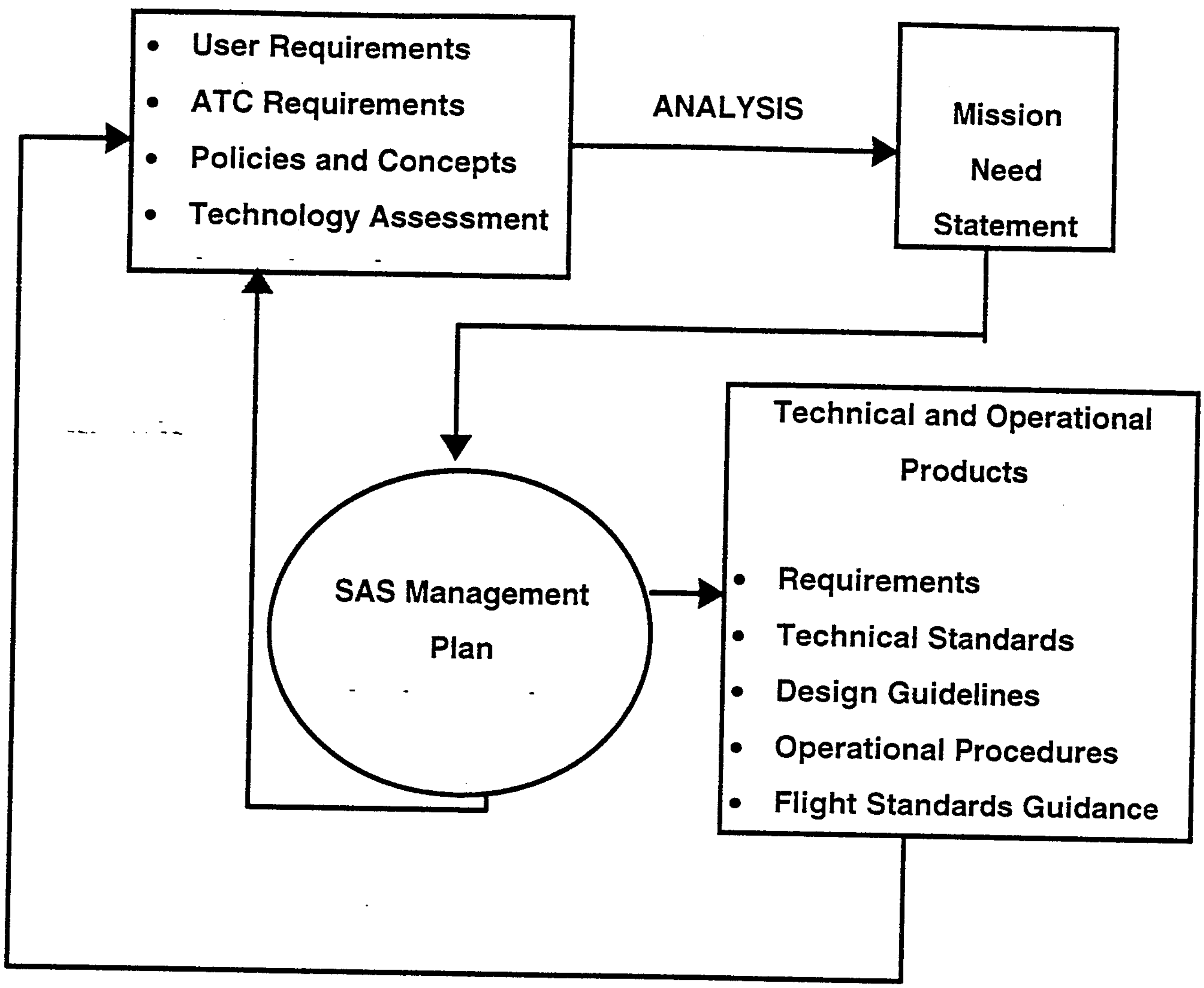


Figure 1-1: Product Development Flow

2.0 PROJECT DESCRIPTION

2.1 Summary of Mission Need

The mission need is to provide increased cockpit situational awareness in order to enhance flight efficiency, overall system capacity, utility, and safety in a GPS-based airspace environment.

The key element in any solution for improving the capacity, efficiency, and safety of the entire airspace system is through the widespread use of advanced technologies to provide pilots, dispatchers, and air traffic service providers with enhanced situational awareness. These benefits will be particularly helpful for those operational activities that presently lack the weather equipment, navigation and landing aids, communications, and surveillance systems available at today's larger commercial air carrier served airports. However, the implementation of safer, more efficient procedures and techniques that these new technologies offer will not occur without the development of a coherent and focused approach by the federal government and the user community. SAS is really about effectively managing technology in a changing environment.

2.2 Overall Objective

Given that technology now exists to enhance situational awareness through the development of affordable equipment that will improve safety through enhanced situational awareness, the overall SAS objectives are to:

- Develop of SAS operational concepts and procedures;
- Create technical design standards and guidelines for the design, certification, and service production of SAS equipment and software;
- Create a compatible ATM supportive infrastructure; and
- Establish incentives that will encourage users to install SAS equipment.

The SAS project will initially consist of upto eleven primary tasks along with a variety of supporting studies and work tasks. A general description of each task is included in Section 5.0, entitled, "SAS Primary Work Tasks," and in Appendix 1 " List and Scope of Additional Studies and Development Tasks." A companion document, entitled "Proposed SAS Work Tasks in Support of the Situational Awareness for Safety Concept," provides detailed additional task listings. The overall objective of these tasks is to expeditiously "deliver" the guidance and assistance necessary for the realization of the primary SAS applications identified in Paragraph 4.5. It is necessary that this effort be completed as soon as possible (preferably by January, 1997) to meet the near-term safety / efficiency / capacity needs of all airspace users. Additionally, managerial methodologies will be

explored to accelerate the process whereby other new technologies and SAS software applications are identified, validated, transformed into technical standards and design guidelines, and accepted by the aviation user and service provider community.

2.3 Assumptions

2.3.1 Technological advances in micro-electronics and telecommunications, GPS-based navigation, computer technology, large memory capacity electronic library systems (ELSs), cockpit and controller displays, graphical user interface software, and off-the-shelf portable lightweight power sources, can be used to develop an affordable "family" of SAS systems for all users. SAS systems.

2.3.2 Government and private sector initiatives will be developed to encourage all users to equip and use SAS in at least a basic "transmit only" ADS-B format <u>without</u> a display.

2.3.3 Providing increased situational awareness for all operators, dispatchers, and controllers will contribute to enhanced safety, capacity, and efficiency of flight operations in all airspace domains.

2.3.4 Providing ADS-B traffic location information to ATC will enhance safety, increase ATC efficiency, increase capacity, and increase ATC's ability to assist operators in all airspace areas.

2.3.5 SAS equipment will enhance access to, safety of, and control of Special Use Airspace (SUA) and Military Training Routes (MTRs).

2.3.6 SAS enhancements can be used to provide flightcrews and controllers with information on non-aircraft airspace operations such as ultra-lights, hang-gliders, aerostats, radiosondes, and descending parachutists.

2.3.7 Enhanced cockpit situational awareness, especially with respect to location, will significantly reduce trespass into Class B, C, and D airspace, as well as special use airspace, resulting in fewer pilot deviations.

3.0 SAS MANAGEMENT

3.1 Overview

Project management will deal with the "strategic" as well as "tactical" oversight needed to develop standards and procedures for the use of SAS applications. The tasks described in Section 5.0 are intended to provide standards and guidance needed for implementation of the primary (and other) SAS applications. Individual task plans will be developed to establish schedules, controls, responsibilities, coordination, control/feedback, and accountability requirements to accomplish each task. Tasks development to support a more complete list of SAS work tasks to be developed is included in Reference # 37 to Appendix 9. Additional SAS applications will be considered in the SAS project review and planning process.

3.2 Roles and Coordination Responsibilities

Overall management and coordination of SAS is the responsibility of the General Aviation and Vertical Flight Office, AND-610. The Flight Technical Program Office, AFS-400, is the "project sponsor" on behalf of the user community. ATR-330, NASP and Future Systems Branch, is the air traffic "focal point" for the SAS process. AND-610 staff member(s) will be assigned to manage and coordinate with air traffic, flight standards, certification, and organizations, and other federal and non-federal organizations. This "team" will provide program direction and accomplish the necessary internal and external coordination within the context of the FAA's Integrated Product Team (IPT) concept.

Coordination of inputs and requirements from other internal and external organizations is essential to the achievement of an acceptable SAS end product. International and private sector coordination will require continuous liaison between FAA and the cognizant management committees of ICAO, relevant technical organizations (e.g., RTCA, SAE, IACC, etc.), and appropriate labor, professional, and user groups.

Coordination will consist of both formal and informal methods. Formal coordination will be effected through working groups and coordination papers. To ensure control and timely coordination, a documentation and tracking system will be established. Points-of-contact (POC) will be established within each organization concerned with SAS activities and will become part of the IPT. Working groups will also be established from these IPT members. To ensure current knowledge of project activity and the opportunity to comment or intervene, all meetings will be documented by memorandum or minutes and distributed to all participants.

The organizations identified in the following paragraphs comprise an initial list of IPT members. SAS IPT members must remain abreast of the status and content of other

projects from the REandD and FandE arenas that relate to SAS. This will be accomplished by review of the documentation for these projects, frequent informal discussions with associated project managers, attendance at internal meetings, attendance at RTCA related committee meetings, and the dissemination of summaries of interest to the sponsoring organization. A SAS electronic bulletin board will be established to provide much of this material.

3.2.1 Research and Development. Parallel activities in programmatic development of weather information collection and dissemination technology, data link, separation assurance, and terminal area traffic management require close coordination of SAS tasks with other research and acquisition offices.

3.2.2 Air Traffic. The collateral technologies on which SAS is based (e.g., ADS, ADS-B, GPS, and data link) may require additional reviews to determine the impact on ATC and flight procedures. The SAS Project Manager must maintain close coordination with the responsible AT offices and be involved in system development. Successful coordination will define the operational framework and procedural infrastructure to accomplish the full potential of SAS. These offices include as a minimum: ATZ-100, ATP-100, ATM-100, and ATR-300.

3.2.3 Flight Standards. A number of flight standards "products" will be required with the development and implementation of SAS. Development of these products will require close coordination with all AFS divisions.

3.2.4 Additional FAA Coordination. Elements that require less frequent but regular coordination include: AVN, ASE, ASC, ARP, API, ABB, AAM, ARM, AAF, AAI, AIR, AGS, CAMI, AGI, AEE, Regional Aircraft Certification Offices, and others as requested.

3.2.5 Impacted Organizations outside FAA. Include but are not limited to: ATA, AIA, GAMA, FSF, EAA, NATA, NASA, SAMA, NBAA, HAI, DOD-DMA, DOC-NOAA, DOD-ARPA, AOPA, AOPA/ASF, RAA, AHS, NTSB, USGS, USAF-OSR, USAF-FDL, AFFSA, DOI-BLM, USAASA, RTCA, and SAE.

3.2.6 Professional and Labor Organization Involvement. ADF, ALPA, APA, ISASI, NAATS, and NATCA

4.0 ACTIVITIES, PROCESSES, RESPONSIBILITIES, AND PRODUCTS

4.1 Sequence of Major Activities

Figures 4-1 and 4-2 reflect the plan "process" for SAS concept and task development. Detailed task plans will be developed in accordance with direction from the SAS Steering Committee.

4.2 Strategy

The approach or strategy for the SAS initiative consists of a practical review of associated technology and projects; identification and establishment of the operational environment; articulation of user, provider, and labor generated operational requirements and procedures; determination of the need for and conduct of additional studies; joint public / private partnership development and validation of prototype SAS equipment to assist in the development of applicable technical standards and design guidelines for manufacturers. Additionally, flight technical standards, accompanying guidance material, and operational specifications, will need to be developed and promulgated by AFS.

4.2.1 Technology and Review of Associated Projects

Careful review of related projects and activities will be continued to maintain an awareness of REandD and CIP projects and activities being conducted by: other FAA organizations, commercial and academic sources, DOD, and NASA. As part of this effort, appropriate changes and additions will be developed and provided to documentation revisions for related projects and project descriptions in the REandD Plan and the CIP. All pertinent SAS related information will be reviewed and compiled from existing SAS-related documentation; see Appendix 9, "References". Additionally, some SA tasks will be, or are being performed, by other FAA, NASA, DOD, or industry elements. It is not the intent of this SAS project to duplicate or supersede these activities. The SAS Project Manager is responsible for ensuring coördination with the performing activity to ensure timely integration of these activities into the SAS project.

4.2.2 Establish Operational Environment

Based on an understanding of existing and planned NAS and ICAO system architecture, continue to refine the operational environment for SAS. The SAS Project Manager will continue to ensure current knowledge of data link, GPS and other operational environment

determiners. The SAS Project Manager will coordinate this knowledge with members of the SAS System Requirements Team (SRT). The SRT will be composed of representatives from the FAA, the users, and labor interests. Likewise, input from the SAS initiative will be provided to other NAS initiative committees and SRTs to establish procedural and equipment compatibility and interface.

4.2.3 Formalize Establishment of Operational Requirements

The SAS Project Manager will establish a SAS Systems Requirements Team (SRT) composed of FAA, user, and labor representatives, to review the requirements generated from previously held meetings such as the Experimental Aircraft Association (EAA) SAS Workshops held in 1993-1994, the FAA Strategic Plan, Executive Level Guidance, the three National Business Aircraft Association (NBAA) SAS User Group Meetings, held on 8/25/94, 9/13/94, and 11/17/94, and the SAS reference material contained in Appendix 9. The SRT will represent all airspace user groups as well as aircraft certification, flight standards, labor, and air traffic. This group will operate like the FAA's CIP system. The SAS SRT will document meetings with minutes, working groups, action items and tasking statements.

4.2.4 Studies

The Project Manager, through the SAS SRT, will obtain sufficient data to establish standards for SAS equipment development in areas such as cockpit human factors, data base, SAS data link, certification and continued airworthiness, flight management systems (FMS), SAS system integration, and international harmonization. Such studies will include:

- Combined technical, economic, institutional, and operational feasibility studies for all identified SAS applications;
- From a human factors perspective, efforts to define the SAS cockpit "work station" platform (e.g., design standards and requirements for the next generation cockpit workstation) to support various SAS applications;
- Identifying the ADS-B format and message content needed to support SAS applications and "free flight." (These additional data link messages are called air-to-air "cross link" messages.)
- Accompanying studies to determine the benefits and costs of implementation for each specific SAS application, as well as the synergistic benefit derived from a total "systems approach" to Aeronautical operational Control / Airline Operations Center (AOC)-FMS / FNS-SAS-ATM integration.

> Note: This comprehensive analysis will consist of a "matrix approach" and could examine the benefits and costs to each user segment, to the air traffic service provider, as well as to the FAA in general. Unless otherwise directed by the Project Manager, for the "high-end" air carrier SAS applications, a payback period of only one year will be used in light of the

present economic environment. For general aviation interests, an "equivalent" return on investment will address issues such as less control, increased utility, efficiency, and "peace-of-mind". Maximum use will be made of previous studies dealing with related topics and benefit analyses.

4.2.5 Develop Needed Prototype(s)

The Project Manager, through the SAS SRT, will determine which prototypes, if any, are necessary, practical, and affordable while validating proof of concept and assisting in the development of technical standards and design guidelines.

4.2.6 Public Policy and "Incentive" Analyses

Appendix 5 provides a listing of public policy-related issues that will need to be addressed as part of this SAS concept initiative, e.g., a study to determine the costs, benefits, and utility issues supporting a public policy decision concerning the purchase (or assistance in the purchase) by the government of a battery powered or ship-powered ADS-B-based "Transmit only" device without a display. The analysis will also provide information on other incentive plans that would induce users to equip with SAS equipment and software.

4.2.7 Develop Technical Standards and Design Guidelines

The Project Manager, through the SAS SRT, will coordinate development of applicable technical standards and design guidelines for the manufacture of equipment that provides aircraft operators with improved cockpit-based "aircraft" and "external" situational awareness. Both new aircraft equipage and retrofit of existing aircraft will be addressed.

4.2.8 Develop Procedures

The Project Manager will coordinate the establishment of projects and tasks that result in the development of air traffic and aircraft operational procedures and maximize the benefits of SAS equipment. This process will also consider regulatory review requirements.

4.3 Relationship With Other Projects

The SAS Project is related to numerous other projects in the CIP.

Coordination of those activities under the SAS initiative must ensure that CIP projects underway are compatible, protocols observed, and integration of equipment is facilitated. Each of the listed SAS projects comes with a set of related projects in the REandD Plan and the CIP which must also be considered. These projects include, but are not limited to the following:

4.3.1 The Flight Operations and Air Traffic Management Integration Project, (FTMI) REandD Project 022-150, will establish the operational requirements for flight operation procedures and standards using FMS / FNS capabilities to enhance system capacity and flight efficiency. (From the FTMI-mission need statement comes this SAS initiative as well as the " Flight Management System - Air Traffic Management System - The Next Generation" (FANG) initiative, designed to promote the exploitation and integration of future FMS, FNS, AOC, and ATM systems for optimum control and efficiency of aircraft and airspace management operations.

4.3.2 The Oceanic Air Traffic Automation Project, REandD Project 021-140, combines three projects; Automatic Dependent Surveillance (ADS), Dynamic Ocean Track System (DOTS), and Oceanic Automation to increase oceanic air traffic capacity and efficiency.

4.3.3 The Aeronautical Data Link Project, CIP Project 23-05, develops a digital telecommunications system to provide a variety of weather and ATC data link services.

4.3.4 The Aeronautical Data Link Communications and Applications Project, CIP Project 63-05, develops an aeronautical data communications infrastructure with ATC and flight information service (FIS) applications.

4.3.5 Other related FAA mission need statements include: MNS # 42, Aeronautical Data Link Communications and Applications; MNS # 171, Traffic Alert and Collision Avoidance System; MNS # 187, Flight Deck Human Factors; MNS # 188, Flight Deck/ATC Integration; MNS # 212, Airport Surface Traffic Automation, and MNS # 259, General Aviation Renaissance.

4.3.6 The NASA / FAA / Industry Advanced General Aviation Transport Experiment (AGATE)

4.3.7 Other Agency Initiatives: SAS will serve to harmonize related avionics and supporting technology initiatives within NOAA, DMA, USGS, ARPA, USAF-OSR, USAF-FDL, DOI-BLM, and NASA Ames and Langley.

4.4 Products

As stated above, SAS initiatives will produce numerous products which primarily involve development of standards in concert with RTCA, SAE, IACC, and others, through definition of an electronic cockpit work station for the future as well as supporting software. Of overall importance will be the necessary technical, flight, and aircraft certification technical standards encompassing standardized icon oriented displays, human factors design guidelines,

hardware/software standards, and Plug-and-Play (PnP) standards for equipment interfaces. Additionally, international technical and flight standards must be developed in coordination with appropriate organizations. Anticipated SAS technical standards and design outlines are contained in Appendix 3.

4.5 Initial SAS Applications Selected for Concept Validation

Based on input from user, provider and associated labor representation, the following primary SAS applications have been selected for validation, with supporting technical standards.

The SAS "Basic" System For Validation:

1. **GPS moving map** with "2D" terrain overlay. **

2. **Weatherlink** (with tie-in during the demonstration to an air carrier AOC. Also, up-link of Nexrad, GOES, TDWR / ITWS data direct to the cockpit.

3. **Traffic Situation Display** (TSD) using ADS-B, i.e., basic traffic advisories. ****

SAS "Advanced" Options For Validation:

4. **Controlled Flight Into Terrain** (CFIT) avoidance using a "3D" database.

5. Graphical "Tunnel-in-the-sky" / "Pathway-in-the-sky" presentation of a standardized **curvilinear "floating waypoint" GPS approach** merged with terrain and obstruction data along with a tie-in to an FMS or lower cost flight navigator system.

** This validation initiative may be expanded to include the graphical display of a conventional GPS-based instrument approach procedure chart.

**** This display option may be expanded to include wake vortex avoidance and /or visualization, in-trail descent, and for use as an airport surface movement aid.

SAS Air Traffic Validation Tie-in:

6. ADS-B **reception at a remote airport with ATC tie-in** to the controlling facility. (This would allow air traffic to evaluate the operational feasibility of applying radar separation standards in a non-radar environment).

7. ADS-B reception at a remote (en route / terminal) location with tie-in to the nearest AFSS. (This demonstration would provide the FSS / EFAS Specialist with greater situational awareness with respect to the aircraft being worked).

SAS Part-Task Training Validation Tie-in:

8. An "off-line" PC based training module to support one (or more) of the above applications. An evaluation of the **usefulness** of this training concept would be conducted as part of this initial SAS development.

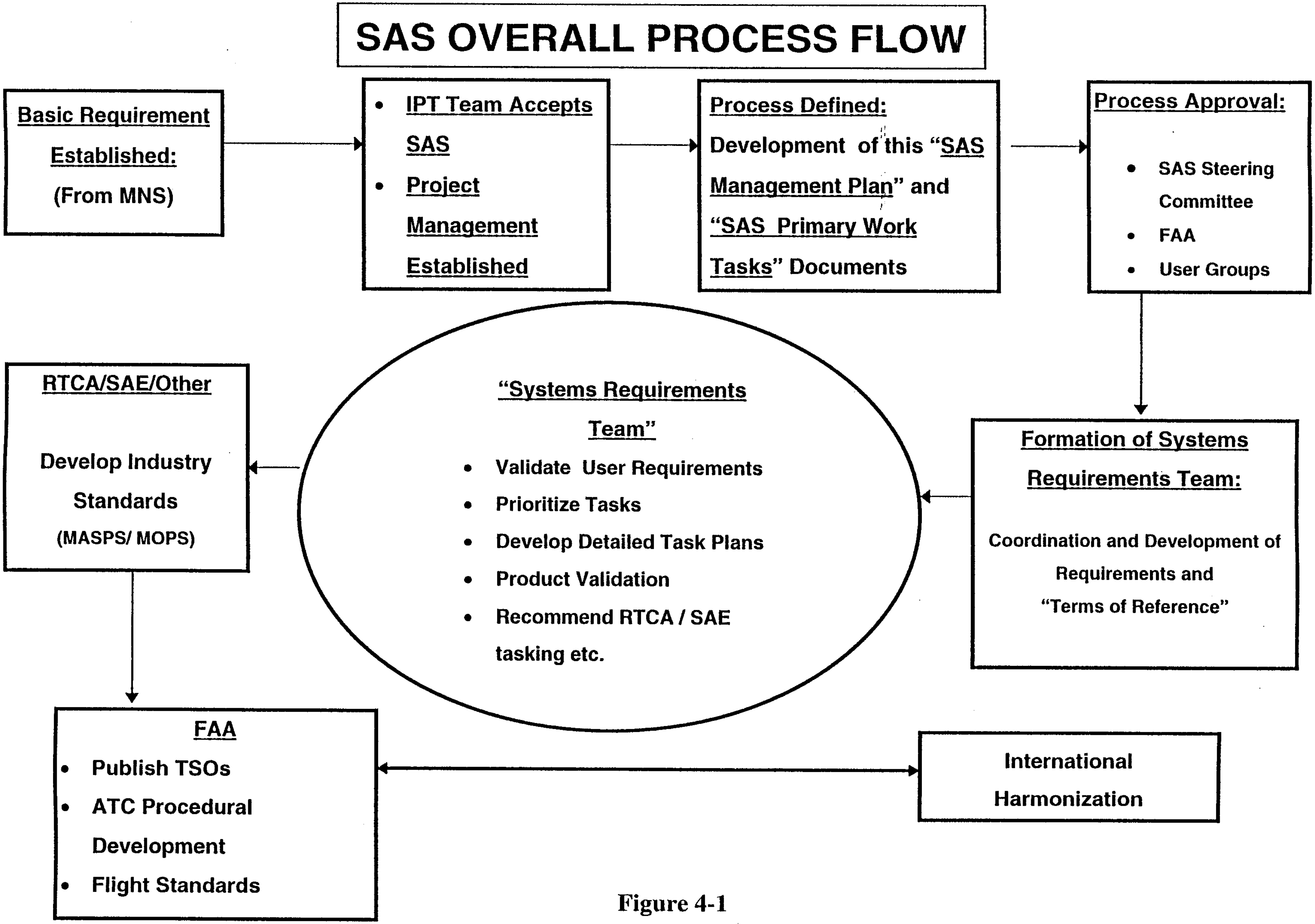

SAS OVERALL PROCESS FLOW
Basic Requirement Established: (From MNS)
IPT Team Accepts SAS
Project Management Established
Process Defined:
Development of this "SAS Management Plan" and "SAS Primary Work Tasks" Documents
Process Approval:
SAS Steering Committee
FAA
User Groups
Formation of Systems Requirements Team:
Coordination and Development of Requirements and "Terms of Reference"
"Systems Requirements Team"
Validate User Requirements
Prioritize Tasks
Develop Detailed Task Plans
Product Validation
Recommend RTCA / SAE tasking etc.
RTCA/SAE/Other
Develop Industry Standards
(MASPS/ MOPS)
FAA
Publish TSOs
ATC Procedural Development
Flight Standards
International Harmonization

Figure 4-1

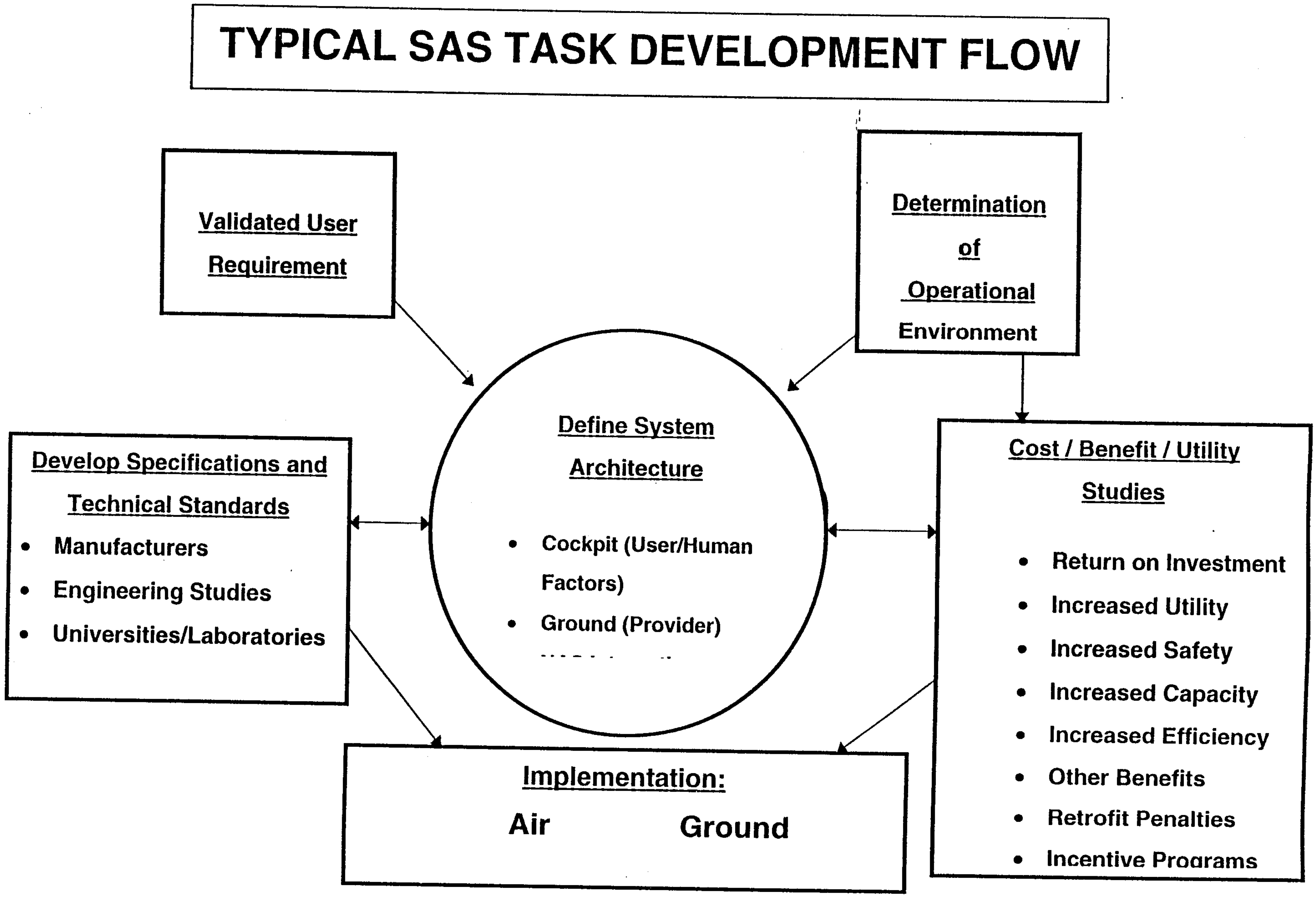

TYPICAL SAS TASK DEVELOPMENT FLOW
Validated User Requirement
Determination of Operational Environment
Define System Architecture
• Cockpit (User/Human Factors)
• Ground (Provider)
Develop Specifications and Technical Standards
• Manufacturers
• Engineering Studies
• Universities/Laboratories
Cost / Benefit / Utility Studies
• Return on Investment
• Increased Utility
• Increased Safety
• Increased Capacity
• Increased Efficiency
• Other Benefits
• Retrofit Penalties
• Incentive Programs
Implementation:
Air
Ground

Figure 4-2

5.0 SAS PRIMARY WORK TASKS

The schedule of SAS applications proposed as part of the initial SAS validation effort is intended to meet a user generated timetable for validation by January 1, 1997. The SAS project is also intended to provide product specifications in consonance with a trend towards a 3 to 5 year half-life or quicker for computer electronics and telecommunications technology driven equipment. While it is understood that the "low-end" SAS system will be relatively inexpensive and focused on providing utility to general aviation, the corresponding "high-end" SAS system is intended to have an appropriate economic pay back for commercial air carrier operations.

Along with Appendix 1, Paragraphs 5.1 through 5.11 support major SAS REandD initiatives. Additionally reference # 37 in Appendix 9, entitled, " Proposed SAS Work Tasks in Support of Situational Awareness for Safety," also contains specific work tasks that embody, complement, and expand upon the content of the following paragraphs.

Both documents should be reviewed together to appreciate the full scope of SAS related REandD activities that have been identified to date.

5.1 DEVELOP AN OPERATIONAL REQUIREMENTS DOCUMENT AND ESTABLISH STEERING GROUP CHARTER

5.1.1 Task Overview and Purpose

Extensive effort has been expended to assess the interest in and identify the need for this SAS initiative. The results of these activities are discussed or referenced in the text of this Plan, or included in the references to Appendix 9. (Additional "need" definition is also underway for SAS ADS-B related activities as part of the newly formed RTCA SC-186. This task will expand on the above results through a process to formalize SAS requirements in the form of an "official" Operational Concepts and Operational Requirements document. It will continue efforts to establish a charter for the "Ad Hoc" SAS Steering Group and will establish the formal relationship between the Project Manager and the "Ad Hoc" SAS Steering Group. These documents the activities of SC-186 and the accompanying charter(s) will facilitate the rapid and orderly development of the technical and operational standards, requirements, guidelines, procedures and processes necessary to implement the various SAS concepts and incentive programs and to encourage maximum utilization of SAS equipment and capabilities.

5.1.2 Task Description

This task will continue to refine the operational environment for SAS based on research of

existing and planned NAS system architecture.

This task will address our current knowledge of data-link, GPS, and other operational environment determiners that the user will face in the foreseeable future. A "team" consisting of users. labor, and service providers will review the past accomplishments of the SAS initiative with the objective of refining and formalizing the definition of the operational environment and SAS operational requirements.

5.2 DEFINE SAS COCKPIT "WORK-STATION" (AIRCRAFT)

5.2.1 Task Overview and Purpose

Components of the SAS system must be capable of retrofit into existing electromechanical and first generation "glass" cockpits while allowing expansion and inclusion on all newly manufactured and future aircraft. The operating system (and supporting cockpit-based SAS workstation(s)) will provide a very user friendly, intuitive operating system whereby an operating manual will only be minimally needed. A pilot will need to learn how to operate the GUI work-station. For each SAS application, "off-line" PC based SAS instruction will be integral to learning how to operate the workstation's graphical user interface as well as each supporting SAS applications.

5.2.2 Task Description

This task will define the SAS specifications and standards for workstations for use in aircraft.

Allowing for expansion , the SAS cockpit workstation for both air carrier and general aviation will be modular in design, using a "Plug-and-Play" (PnP) concept. PnP uses common interfaces and protocols to enhance integration. Because of the commonality of interfaces and protocols, limited new procedures and hardware will be required for enhancements. Initially the SAS system prototypes will be hardware driven, but after initial systems development and refinement of design, the system will become predominately software driven (although changes in technology or user needs may dictate new hardware). The task team will strive for a common "global" software operating system that allows for a graphical user interface (GUI). The team must also evaluate the human factors that affect the ability of the pilot to use the cockpit workstation. Of specific interest is the ability of the SAS workstation to effectively communicate FMS / FNS "mode shifts" and control displacements to the pilot in and effective and timely manner.

5.3 GPS NAV / MOVING MAP DISPLAY OF IN-FLIGHT POSITION/ LOCATION, INCLUDING "2D" TERRAIN DATA BASE

5.3.1 Task Overview and Purpose

The ability of the pilot to view the aircraft's flight path graphically and location during airport surface operations, as well as during departure, en route, terminal, and the approach phases of flight has become a reality with the advent of GPS. This task team will evaluate methods to create and display GPS NAV/moving map presentations, approach guidance, and a "2D" terrain data base as a graphically-based system to be made available to all airspace users.

5.3.2 Task Description

The task will define specifications and standards for a GPS-based NAV / moving map display with an imbedded "2D" terrain data base along with the development of commercially available charting products. Emphasis will be placed on defining the specific information required during each phase of flight. The use of national resources, e.g., DMA, USGS, NOAA, and other databases will be examined in the context of defining a common set of symbology and product "layering" requirements. A study of the human factors involved with moving map display presentations, dual use HSI and "Tunnel-in-the-sky" / "Pathway-in-the-sky" presentations, and information transfer presentations will be conducted.

5.4 WEATHERLINK

5.4.1 Task Overview and Purpose

Weatherlink is the ability to transmit weather information between an aircraft and a ground station, from a ground station to the aircraft, from one aircraft to another aircraft (either real-time or "delayed" via a ground-based "repeater" station, or any combination thereof). The type of information transferred is dependent upon the needs and requirements of the user. The pilot, using a default setting, would be able to determine the area of influence and interest to be displayed throughout the flight, with data link connection and update schedules performed automatically with minimum flight crew interaction.

5.4.2 Task Description

This task will define what information is required by the pilot during flight. Previous work performed by RTCA SC-169 will be utilized as well as a review and analysis of supporting SAS documentation. Specifications and standards will be established for each type of weather

information data link transmission product, as needed. The weather information data link transmission would be in graphical (e.g., weather map, GOES imagery, or weather "radar" images), textual, or a combination graphic / textual mode. Additionally, the task will define when one type of weather information data link information is more appropriate than another product, e.g., a weather map to avoid in-flight weather or textual / terminal weather information during VMC conditions. Note: A Flight Information Services MOPS is under development within SC-169, WG 3. Possible data link transmission techniques may include satellites and cellular-based technology, digital HF, digital VHF, and UHF (including Mode S). Both "request / reply" and broadcast technologies will be investigated.

5.5 COCKPIT TRAFFIC SITUATION DISPLAY (TSD) AND OTHER APPLICATIONS

5.5.1 Task Overview and Purpose

A cockpit display of traffic information (TSD) allows the pilot to conduct safer operations during VFR and IFR flight operations. Additionally, capacity and efficiency will be enhanced through use of advanced applications such as passing maneuvers and station keeping. The proposed SAS TSD application for "high end" users will include, TCAS IV functionalities along with a Tactical Conflict Probe (TCP) function to allow for free flight and conflict avoidance.

5.5.2 Task Description

A review of the current TCAS specifications and standards will be undertaken along with participation by AND and AFS staff elements at RTCA SC-147, SC-186, and other RTCA meetings. Additionally, human factors analysis of the depiction of traffic to the pilot will be conducted within the context of multi-tasking on a single MFD. A study will evaluate the GPS ADS-B data link requirements, i.e., SAS required information that would be transmitted to other aircraft and to the ground. Specifically the ground ATC facility may require integration and additional information, i.e., RA's in progress, aircraft ID, and radio call sign. In addition, the specification and standards on the rate of data link transmissions to accommodate the movements of both the slowest and fastest aircraft in the NAS will be conducted. A study of the cost/benefits to the user community to equip with ADS-B will be performed, resulting in a cost/benefit matrix.

5.6 CONTROLLED FLIGHT INTO TERRAIN (CFIT) AVOIDANCE

5.6.1 Task Overview and Purpose

Each year, controlled flight into terrain (CFIT) is the cause of many accidents. SAS, using the accuracy of GPS positioning and the sophistication of "2D" and "3D" terrain / obstruction databases, will be used as the basis for an advanced ground proximity warning system (GPWS). Unlike currently installed GPWS systems requiring several boxes and expensive modifications, the SAS CFIT system will use predictions based on the GPS position and vectors combined with knowledge of terrain / obstructions in the database to alert the pilot to unsafe conditions. There are two separate initiatives within this task; a simplified "2D" system that simply provides terrain and obstruction warnings based, to a large degree on the work of NOAA's "Off-Route Obstruction Clearance Altitude (OROCA) data file, and a more sophisticated "3D" graphical display of terrain and obstructions.

5.6.2 Task Description

An analysis of the SAS CFIT avoidance system will evaluate the requirements for various aircraft types / missions, i.e., a slow moving aircraft will not require the same degree of sophistication as a more complex, faster moving aircraft. For example, a high performance aircraft may be equipped with an advanced "3D" CFIT software application. For "3D" version, a human factors study of the "3D" system will evaluate how best to display "3D" data in conjunction with the "tunnel-in-the-sky"/ "path-way-in-the sky" presentation or other forms of alerts and airspace guidance, all within the frame-work of a multi-tasking GUI. Additionally, the depiction of the CFIT information on either a "heads-up" or "heads-down" display will be examined. Following these studies, the specifications and standards for "2D" and "3D" SAS CFIT will be developed.

5.7 GRAPHICAL "TUNNEL-IN-THE-SKY"/"PATHWAY-IN-THE-SKY" PRESENTATION OF A GPS "FLOATING WAYPOINT" CURVILINEAR APPROACH AND OTHER COURSE GUIDANCE

5.7.1 Task Overview and Purpose

The GPS "floating waypoint" curvilinear approach allows an aircraft to fly an instrument (or a visual approach) into airports using the GPS precision positioning capabilities and the "3D" CFIT capabilities from the previous task. Aircraft will safely maneuver at night, IFR, or to avoid noise sensitive areas <u>without</u> following a pre-determined "straight-in" track over the ground. In addition to normal "3D" terrain data, added departure/obstruction data in the ELS will provide the pilot with obstruction clearance data for performing a missed approach or rejected landing under normal or abnormal conditions.

5.7.2 Task Description

This task assesses the economic and operational desirability of such a procedure, followed by a technical assessment of aircraft SAS displays to combine the "tunnel"/ "pathway" display of a multi-waypoint GPS approach with the terrain and obstruction ELS data file to create a blended product. A human factors study of the blended approach will examine the pilot's requirements and the ability to accurately display all required information in an appropriate manner. The study will also establish the requirements to provide a GPS curvilinear departure for an engine-out departure. Standards and specifications for the display of curvilinear approaches will be developed. Another human factors study will define a GPS approach chart in "landscape" format which would allow the pilot to correlate displayed cockpit information with approach chart information. GPS "landscape" approach plate format specifications and standards will be developed as part of this effort in conjunction with AVN.

5.8 ADS-B RECEPTION AT A REMOTE AIRPORT WITH TIE-IN TO A CONTROLLING ATC FACILITY

5.8.1 Task Overview and Purpose

ADS-B has the potential to provide ATC with the ability to provide radar separation standards in a non-radar environment. Based on the accuracy of the GPS derived position, ADS-B has the potential to reduce aircraft separation requirements in non-radar environments. These applications will be especially important in those areas where radar coverage is limited, i.e., at non capacity driven airports without radar coverage, in mountainous areas or anywhere when the minimum vectoring altitude is above the floor of Class E airspace. GPS ADS-B also has the potential to provide GPS derived aircraft position on the airport surface, to other aircraft and to air traffic control, a potential that could be exploited to provide ASTA-like services at many smaller, controlled airports, or at many smaller, uncontrolled airports that can not justify installations of a complete ASTA system.

5.8.2 Task Description

Specifications and standards will be developed to define the ground ATM infrastructure to support air traffic requirements following a study of the operational environment(s) and various SAS applications that may be encountered. There may exist a need to define different requirements for different types of operational environments, i.e., the midwest plains may allow for fewer or a different type of ADS-B ground-based receiver than the wilderness of Alaska. The study will also evaluate the capabilities of different types of ADS-B data links, i.e., Mode-S, MLS Band "spread spectrum" technology, VHF, other UHF data link, etc. Specifications and standards for ADS-B data link format will be developed. Development of an acceptable GPS ADS-B standard is pivotal to the entire SAS concept. A supporting study

will also evaluate changes to ATC procedural to support ATC adoption of ADS-B as a means to monitor and separate traffic.

5.9. ADS-B RECEPTION AT A REMOTE (EN ROUTE / TERMINAL) LOCATION WITH TIE-IN TO THE NEAREST AFSS

5.9.1 Task Overview and Purpose

ADS-B has the potential to provide the FSS / EFAS specialist with increased situational awareness with respect to aircraft being "worked." Not only would the FSS / EFAS specialist use ADS-B to obtain position correlation for pilots that are temporarily disoriented, but weather information data link would allow for safety of flight information to be provided to and from the aircraft. (For low-time pilots, the EFAS specialist could also assist in the interpretation of the data link weather products.) The latter capability would be especially important to pilots with limited flying ability and/or experience. For aircraft not equipped with weather information data link, instead of a verbal generalized weather forecast, specific weather and other flight related information could be transmitted to any pilot for in-flight use, followed by an interactive dialogue with the specialist. Whenever possible, the FSS/EFAS specialist could also obtain en route weather information from properly equipped aircraft through either a manual or electronic PIREP downlink / uplink function. This would allow for an increase in the overall accuracy of flight information provided to pilots.

5.9.2 Task Description

Specifications, standards, and procedures will be developed for ADS-B and weather information data link data link modes following a study of the operational environment(s) that will be encountered. There may exist a need to define different requirements for different types of operational environments.

5.10 "OFF-LINE" PC BASED TRAINING MODULE TO SUPPORT SAS APPLICATIONS

5.10.1 Task Overview and Purpose

The use of desktop "PC" type computers for "off-line" training is becoming accepted within the flight training community. Computers can combine low cost with individualized training. The modular SAS hierarchy of a "core" cockpit work station with discrete software applications particularly lends itself to PC based training. A PC based training system can train to reinforce intuitive logic and develop positive habits. Current computer graphics

capabilities allow for repetitive training using identical displays without the high cost of a full motion (or full task) simulator.

5.10.2 Task Description

This task will develop two computer based instruction modules. Applications will be Windows and Apple based, thus allowing for the widest range of users. The team will develop an application module to support two task areas as outlined in this SAS Management Plan, with the advice and guidance of the Steering Committee. A human factors study will evaluate the application module's usefulness as an aid in training the pilot outside of the aircraft to a high degree of proficiency. Another human factors study will examine the usefulness of PC based training in increasing pilot decision making skills. Standards will be developed for the SAS PC based training modules.

5.11 SUPPORTING STUDIES (SUCH AS A TECHNICAL, OPERATIONAL, INSTITUTIONAL, AND ECONOMIC ASSESSMENT)

5.11.1 Task Overview and Purpose

It is imperative, very early in the SAS concept definition process, to carefully and systematically prioritize and evaluate all the SAS applications identified to date. A list of all known SAS applications is contained in Appendix 2 "List of Candidate SAS Applications". Findings will enable decision makers, both in and out of government, to make better, more balanced decisions.

5.11.2 Task Description

A "matrix" study will be conducted of all SAS applications identified to date. This "matrix" study will be cross referenced to each user segment, to include: ultralights, hang gliders, sailplanes, and gliders, vintage/classic GA, recreational use GA, business use GA, corporate GA, on-demand air taxis, commuter/regional airlines, air carrier operations, public use (local, state and federal government), and Department of Defense airspace users. The special user needs of Emergency Medical Service (EMS) rotorcraft will also be addressed.

Specific study elements will include prioritization of applications, technical, operational, institutional and economic considerations, including a benefit-to-cost analysis for each application. The benefits / cost analysis will consider the incremental costs of upgrading to each application along with an analysis of the quantitative/qualitative impact on: safety, airspace utilization, training, capacity, efficiency, and regulatory impact.

Other supporting studies are required to support the work tasks and are identified in Appendix 1, and in reference # 37 to Appendix 9. All these additional work tasks will need to be pursued in order to complete a rigorous definition and systems development of the SAS concept in terms of a "Total Systems Approach."

SITUATIONAL AWARENESS FOR SAFETY (SAS) MANAGEMENT PLAN

PART II

APPENDIX SECTION

March 1, 1995

APPENDIX 1: LIST AND SCOPE OF ADDITIONAL STUDIES AND DEVELOPMENT TASKS

<u>NOTE</u>: Refer also to the document entitled, "Proposed SAS Work Tasks in Support of Situational Awareness for Safety", dated February 15, 1995.

The following are potential tasks that will aid in the accomplishment of the overall SAS project objective. At this point there are several possible tasks that can be performed to meet SAS objectives. These projects are listed without regard to size, category, or functional area. Potential studies include:

1. Establishment of a SAS Reconfigurable Cockpit Work Station Test Bed.

Establishment of a reconfigurable SAS cockpit work station "Test Bed" using existing products that can be interfaced to provide prototype equipment for evaluation and validation of operational concepts. This "platform" could be as simple as a portable "high-end" laptop computer that provide an FMS tie-in. (One such device is the "ASAT" system in use at AVN-210. The ASAT is a "2D" and "3D" airspace and air traffic simulation device being used to collect statistical data from simulated aircraft that fly with full flight dynamics. In short, the targets fly like aircraft and not as programmed computer dots. This system will accept terrain overlays, other aircraft position data, and can be made to operate on a laptop.) The degree of capability will, of course, drive the cost. Many of the following tasks/projects could use this test bed combined with actual aircraft equipped with the laptop prototype and possibly, the General Aviation Research Simulation Device (GARSD) being developed by CAMI.

2. Literature Search and Development of Graphical User Interface (GUI) Guidelines

A major contributor to the success of the SAS concept will be the design of an object-oriented graphic user interface (GUI). A great deal of progress has recently been made in developing and validating standards for a GUI such as that envisioned for the SAS cockpit. Summaries of studies on GUI have been reported in a number of human factors and computer science publications and proceedings of professional meetings. Before specific projects to develop the GUI for SAS are undertaken, there is a need to review existing literature and develop a compendium of lessons learned. The results of the literature review should include at least the following:

- Validated measures of situational awareness
- Information display formats (e.g., object-oriented vs. command-oriented)
- Information interpretation and management strategies (e.g., layering and clutter reduction techniques)
- Input/output techniques (e.g., keypad vs. voice recognition)
- Impact of new and emerging display and input/output concepts and technologies (e.g., voice, virtual retina display, laser lights)
- Mode shift display in FMS / FNS equipped aircraft

3. Assessment of the Technology Base Supporting "2D" vs. "3D" Virtual Reality Displays

In order to implement the SAS concept, it will be necessary to display air traffic and collision avoidance and terrain information in a clear and concise manner to the pilot. (A dual function HSI and "tunnel-in-the-sky" / "pathway-in-the-sky" combination is an example of possible combined display.) Critical and mission tasks will need to be clearly defined. It is now possible to display information using a two- or three-dimensional format. The advantages and disadvantages of each has been examined previously, albeit in an a non-integrated maneuver, for Traffic Situation Display (TSD) and Traffic Alert and Collision Avoidance (TCAS) displays. For example, a single "3D" display can often provide an integrated picture of a situation that might otherwise require adding symbology to a single "2D" display or using two or more "2D" displays. However, "3D" displays until now have been complex and expensive to construct. Cost was related to the need to do real-time, "3D" graphics manipulations for dynamic "3D" displays. Because SAS displays will incorporate functions of TSD and TCAS displays and other Electronic Library System (ELS) files, there is a need to determine if "3D" displays can provide a significant increase in a pilot's situational awareness over that provided by "2D" displays for representative flight scenarios to offset the cost and complexity. In addition, it should be determined when and how best to use "2D" or "3D" displays.

4. Data Link vs. Voice Communication

Electronic data link (both textured and graphical) is an alternative to voice for communicating air traffic, weather, and NOTAM information for the. However, the conditions under which each communication mode are most effective and their effects on pilot performance and workload are not totally understood. There is a need to compare the effectiveness of the two techniques using representative mission scenarios. The scenarios should include surface movement, takeoff, en route, and terminal area operations. In addition, combined display strategies for combining voice and data linked information into one or two displays need to be investigated for critical and mission tasks. Performance measures should include the time to receive and acknowledge the message and message accuracy, as well as a determination of how well complex clearances, instructions, and NOTAM packages are communicated to the pilot.

5. Decision-making Training

An important aspect of the new technologies supporting SAS is their potential for improving the quality of pilot decision making, including the quality and timeliness of decisions. In addition, requirements for maintaining alertness in an automated cockpit during periods of low stress, i.e., "passive" monitoring of displays vs. "active" periods with high stress / high workload need to be studied. Decision-making training includes techniques for recognizing, organizing, and combining the multitude of information that will be available to the pilot in the SAS concept, including for multi-crew cockpits how best to effect resource management in a SAS-based cockpit environment. Recent research in the area of cognitive decision making suggests that pilot decision-making often does not follow the "classical model" in which all alternatives are identified, weighted, and an optimum solution identified. Rather, decisions are based on previous experience with similar situations and a "haste" in wanting to take action. In fact, in some situations, pilots have been so overwhelmed that they "turned off" all advanced automation / FMS systems because they were overwhelmed and / or not aware of what the "system" was doing or was commanded to be done, and then flew manually, and poorly. Furthermore, poor decisions can often be traced to faulty information early in the decision process or due to lack of familiarity with all the "ins" and "outs" of a particular software application, such as an FMS / flight director / autopilot system. Recently studies have been undertaken to develop and validate decision-making models that reflect the operational situation faced by the pilot.

Further research within the umbrella of the SAS concept is required to advance the work already accomplished and to structure the SAS concept to reflect these models.

6. Display Option Combinations

Display technology provides many options for presenting the air traffic, collision avoidance, and weather information required to increase the situational awareness of the pilot. "Platforms" display combinations include a single SAS multi-function display (MFD) combined with a dual-function EHSI or several MFDs that "share" SAS applications, along with "head-down", "head-up", laser light displays, synthetic voice, and others. Experience with military and commercial aircraft suggests that certain types of information may be more suitable to one or the other of these display formats. However, there is a limited experience base for designers to make informed decisions about the location and format of information on the different types of displays in the cockpit. Therefore, there is a need to investigate the effectiveness of these display formats for the types of situational awareness information to be presented by the multitude of SAS applications possible. These studies would lead to the development and/or revision of technical standards for SAS displays.

7. Accident / Incident, Pilot Deviation and Operational Error Data Base Analysis and Safety Impacts Study

There are several data bases available that provide information on aviation accidents, mishaps, and violations that are relevant to the SAS concept. Analyses performed on these data bases often identify "pilot error" as a major contributing factor. In many cases, it is likely that there were design problems or loss of "situational awareness" that had a substantial contribution to the commission of the error, but that were not apparent from the data base. Unfortunately, procedures for collecting accident data do not lend themselves to the identification of error-producing design factors. Therefore, there is a need for a methodology for identifying design-induced errors that are likely in a cockpit designed for SAS along with developing procedures for minimizing or eliminating these errors. As part of this study, an analysis should be conducted to assess where SAS concepts will have major safety impacts in lowering the accident / incident rate for each user segment.

8. On-going Literature Search of Applied Human Factors REandD

An on-going effort, established in parallel with the basic SAS initiative, needs to monitor advances in man-machine interactive technology, and in computer hardware/software developments. As these new technologies are tracked through an on-going literature search, work needs to be done to evaluate the findings of this literature search and whether any of its findings should be incorporated into future SAS applications within the "spirit" and "context" of the proposed SAS PnP modular hardware/software infrastructure.

9. Voice Recognition Equipment with PCMCIA Memory

This technology may have direct application to voice command input to SAS equipment on-board aircraft. Additionally, voice recognition may assist controllers in placing inter/intra facility, and ATM-AOC telephone calls. Voice recognition technology needs to be evaluated, and a set of standardized voice activated commands and phraseology, along with technical standards, need to be developed.

10. Literature Survey of Sun Light Readable SAS Display Technology

Advanced active matrix and cold field emission devices are now being developed. Under this initiative, future trends in resolution, sunlight readability, and costs would be researched.

11. Literature Survey of ELS Technology

What are the industry trends toward higher capacity ELS systems, with high access times and high refresh rates. How will these larger capacity systems impact SAS applications downstream? Another technical issue is whether it makes sense to uplink data via data link or to wait until large memory capacity chips become available at affordable prices.

12. Certification Issues

A policy paper addressing the entire SAS "family" of portable vs. installed, battery powered vs. aircraft powered SAS systems, needs to be developed. It should focus on at least the following: How can SAS technology best interface and "mimic" the new integrated modular avionics designs being developed for the high-end aircraft and can / will this design architecture find a place in the smaller 14 CFR Part 23 end user? What certification standards will need to be addressed to meet "fail tolerant" and "fail operational" design standards for Part 23/25 aircraft? What certification standards are needed to approve "portable" battery-powered SAS systems when their ADS-B message has an ATC / "free-flight" tie-in.

13. Public Policy Issues

Appendix 5 lists 14 ADS-B weather information data link and ELS database policy issues relating to SAS. These issues will need to be addressed in the course of developing and implementing this SAS concept.

14. Other Supporting Studies

Reference # 37 to Appendix 9 lists specific additional work tasks needed to support SAS development. This reference needs to be reviewed along with the work tasks described in this management plan to fully understand the "breadth and scope" of all SAS REandD related initiatives.

APPENDIX 2: LIST OF CANDIDATE SAS APPLICATIONS

> *Note -- Both* ***air carrier*** *and* ***general aviation*** *applications are commingled in the following list, with some applications already in use on a "piecemeal basis" in some aircraft, most notably, those equipped with a "first generation" "glass" cockpit.* ***No formal effort has been made to prioritize the following applications nor to accomplish a technical, operational, economic feasibility or market need analysis.***
>
> *Those applications highlighted in* ***BOLD*** *are those SAS applications that make use of some form of data link.*

FLIGHT PLANNING AND NAVIGATION:

1. **Integrated VFR / IFR preflight planning and waypoint insertion into the SAS / GPS-based flight navigation system or FMS prior to engine start.**

2. **Intuitive, user friendly, ground and in-flight re-planning / re-programming capability along with the appropriate ATM and, as needed, AOC / dispatch / flight-following tie-in.**

3. GPS NAV / moving map (VFR / IFR) display of in-flight location.

4. **Graphical display of "active" Special Use Airspace (SUA).**

5. **Textual and graphical display of ATC assigned clearances and instructions.**

6. **Graphical display of plan and profile ATM-assigned standard instrument approach procedures including depiction of terrain, obstruction hazards, and other ATM assigned restrictions.** This display of instrument approach procedures and holding patterns would make use of an industry standardized symbology.

7. **Graphical display of missed approach, rejected landing, and standard**

instrument departure guidance. Terrain and obstruction hazards would be of sufficient detail to allow terrain avoidance during an engine inoperative departure.

8. **Graphical display of a standardized GPS "floating waypoint" curvilinear approach showing terrain and other obstruction hazards.** (Note: Should tie-in with FMS / flight navigator to achieve maximum benefit).

9. Graphical presentation of VFR traffic patterns (including traffic pattern altitudes) and VFR checkpoints.

10. **A cockpit display of aircraft position on the airport surface along with a graphical display of all ATM assigned taxi clearances / instructions, plus display of all required hold short points. Airport surface movement traffic awareness and collision avoidance (including aircraft on short final) along with "station-keeping" during taxi / push-back operations in both movement and non movement areas.**

11. **A visual display (when airborne) of the airport and airport runway combination to assist in landing at the proper airport, on the assigned runway, and to provide Traffic Situation Display (TSD) (along with station keeping capability) situational awareness during parallel or converging runway operations.**

12. Graphical display of the nearest emergency landing site(s) and the most suitable route to reach those airports.

IN-FLIGHT COLLISION AWARENESS AND AVOIDANCE / ON-BOARD AIRCRAFT SURVEILLANCE / STATION KEEPING:

1. Terrain and terrain avoidance -- either "2D" or "3D"

2. **In-flight traffic information (i.e., TSD using ADS-B) and on-board surveillance / station keeping including Tactical Conflict Probe (TCP). Both the aircraft and the ground would share the same real-time data. As envisioned, there would be a "family" of four GPS based ADS-B systems as follows:**

    - **An ADS-B "transmit only" system <u>without SAS display.</u>**

      This would provide aircraft with traffic awareness of <u>other</u> non-electrical system equipped aircraft and air vehicles that were nearby, using the portable "transmit only" GPS ADS-B option but without any display capability.

    - **ADS-B traffic awareness, i.e., traffic advisories only.**

- **ADS-B collision avoidance, i.e., TA's and RA's for vertical as well as horizontal maneuvers, that is, full TCAS IV functionality.**

- **ADS-B collision avoidance with an on-board conflict avoidance / surveillance capability, i.e., TCAS IV functionality with FMS integration (i.e., TA's, RA's, and Tactical Conflict Probe (TCP) capability). TCP functionality makes use of next FMS waypoint and / or altitude / VSI pre-select" intent" data, and is envisioned as the enabling aircraft-based technology for free flight.**

  Note: Conceptually TCAS IV is to be a GPS based TCAS system using Mode-S between participating aircraft. TCAS IV would include TA's as well as RA's for vertical as well as horizontal maneuvers. At this time there is lack of professional consensus as to whether ADS-B for SAS (in an expanded format to include most if not all SAS broadcast applications) and TCAS IV would be ***one and the same or separate systems.*** *Also, some question whether Mode-S would have the necessary performance characteristics to satisfy the multitude of "SAS mission" requirements envisioned or whether another dedicated "ADS-B" frequency and / or data transmission method is required to satisfy the SAS mission need.*

3. Display of synthetic vision information for approach and landing (i.e., "Head-up" / "Head-down" displays).

WEATHER AWARENESS AND NOTAMS (VIA DATA LINK):

1. **Graphical and textual depiction of pre-departure, en route and terminal area weather.**

   Note: FMS / flight navigator winds, temperature, and other data fields would be transmitted, via data link, directly into the FMS / lower cost flight navigator system.

2. **Graphical display of volcanic ash information.**

3. **Cockpit display of textual and graphical NOTAMS including visualization of temporarily and permanently displaced runway thresholds and closed runways / taxiways.**

4. **Cockpit display of textual and graphical ATIS to flight crews.**

5. **Graphical presentation of the winds on final approach, including touchdown zone surface winds.**

6. Cockpit display of predictive windshear.

7. **Visualization / cockpit display of wake vortex hazards.**

8. **Auto-PIREP "down-linking" and "cross-linking" of selected in-flight weather.**

   Note: "Cross-linking" of weather data could be done either real-time or in a "delayed" mode whereby data would be stored in a ground station then retransmitted upon request.

OTHER AIRCRAFT RELATED APPLICATIONS:

1. Standards for the use, including an acceptable means to obtain timely revisions, of an electronic library of in-flight use reference materials.

2. Standards for the use and display of aircraft checklists.

3. Graphical display of designated airport surface run-up areas (along with a requested heading / alignment while on the ground) to reduce the environmental noise impact to surrounding neighborhoods.

4. Graphical display of airport noise sensitive areas and airport specific noise abatement arrival / departure procedures, if applicable. (This application includes a depiction of the noise sensitive areas in the immediate vicinity of an airport, the noise sensitive areas below the approach corridors to an airport, as well as off-airport noise impacted areas such as National Wildlife / National Park and Federal wilderness areas).

   Note: The FAA has standardized vertical noise departure profiles for aircraft with a certified takeoff gross weight greater than 75,000 lbs. The FAA does not standardize lateral departure profiles; each airport or regional authority has its own standards. There has been no Federal effort to address nor standardize vertical departure profiles for other, smaller air carrier and general aviation aircraft.

5. **Shifting (by ATM via data link) of the FMS / flight navigator waypoints depicting VFR / IFR arrival and departure corridors to noise sensitive airports to accommodate daily variations in the 24-hour average sound level (i.e., DNL) saturation.**

6. Correlation of takeoff, departure, and landing performance data with actual GPS-based aircraft position data. (This would be an automatic take-off performance monitoring sub-system embedded within the overall SAS multi-tasking / GUI software).

7. **In-trail climb, descent, or lateral passing in oceanic airspace. (End-state is called "free flight").**

8. **In-trail climb, descent, or lateral passing in domestic en route airspace. (End-state is called "free flight").**

9. **More precise in-trail spacing in oceanic and domestic en route airspace and / or on final approach (i.e., aircraft separation by distance or by speed). Also, "manual" or FMS "coupled" station keeping.**

10. Graphical display and GPS correlation of flight training maneuvers and related air work (for use in pre- / post-flight instruction).

11. Electronic processing of the GPS "carrier phase" tracking signal, resulting in a GPS-based, emergency aircraft attitude indicator.

12. Electronic aircraft "status" / condition monitoring and display. **Also, periodic condition monitoring, data collection and down link reporting for real-time and post-flight maintenance analyses.**

    <u>Note</u>: SAS would help pilots monitor FMS / FNS "mode" shifts, detect direct and indirect data management errors, system fault errors, and changing ATM - FMS system intentions during periods of low workload (i.e., complacency) and during high workload situations (i.e., periods of high stress).

13. Sensing and display of potentially critical safety events such as missed "Before Take-off" checklist items, icing accumulation on specific airframe components, more effective visualization of a "failed" engine (on a twin engine aircraft), etc.

14. Graphical "range ring" indicating fuel remaining along with an optional display of competitive fuel pricing data.

15. **GPS based ELTs. (Distress and other types of emergency messages could be activated manually and broadcast "in-the-blind" when possible on the appropriate data link frequency). Example: For an aircraft operating in oceanic airspace -- "Lost pressurization; diverting off assigned track and descending."**

    <u>Note</u>: Additionally, some have suggested that ELT and ADS-B hardware components be physically combined into one functional unit to gain certain installation and periodic inspection efficiencies.

16. Electronic recording of GPS position and time data, along with other SAS displayed data, for use in accident / incident investigation and in air carrier internal Flight Operations Quality Assurance Programs (FOQAP), e.g., actual recorded flight path data could be used to later respond to noise complaints. Also, SAS derived data could assist in more accurately defining "probable cause" and thus help reduce the number of unsubstantiated liability cases. Note: The storage of SAS data in non-volatile memory would supplement, not replace, data already being collected by digital flight data and voice recorders.

17. **Air-to-ground "voice" communications using cellular phone technology as a back-up to VHF COMM with ATC (i.e., as lost comm back-up) or for use in other air-ground / ground-air applications.**

    Note: Intent is to allow cockpit access to public telephone switch networks as an emergency back-up to loss VHF comm or for pilot personal use.

PART-TASK SAS TRAINING:

1. PC based instruction and part-task simulation for initial and recurrent SAS training (for student pilot through air transport pilot) -- applicable for general aviation through air carrier initial training.

AIR TRAFFIC AND FLIGHT SERVICE STATION (FSS) APPLICATIONS:

General Comment # 1: Enhanced AOC-ATM ground interchange of data will be needed to efficiently nurture several of the SAS applications.

General Comment # 2: The following applications are only possibilities. They have not been accepted as validated requirements or services.

1. **Controller display of in-flight aircraft position data based on GPS ADS-B data, along with FMS programmed next waypoint "intent" when available. This specific SAS application would include both domestic (including Alaska and Hawaii) and Gulf of Mexico airspace. This application could include:**

    - **ADS-B reception at remote airports with tie-in to the controlling air traffic facility. This procedure would allow air traffic to apply "pseudo" radar separation standards in airspace that presently does**

not have radar coverage.

- ADS-B reception at a remote location (i.e., en route / terminal) with tie-in to the nearest AFSS.

  Note: *This latter capability would provide the FSS Specialist with a cost effective means to gain enhanced "situational awareness" from which to conduct in-flight weather briefings as well as a means to perform ADS-B based "DF" pilot steers.*

2. Controller display of airport surface movement activity and a means to ensure aircraft conformity with ATC assigned taxi clearances, i.e., ASTA and ASTA-"Lite".

3. ADS-B based controller display of precision parallel runway alignment / monitoring. Tie-in with the Precision Runway Monitoring (PRM) effort.

4. Controller display of down-linked aircraft approach speed (for spacing) and actual factored AFM data distance requirements (for LAHSO). (Combination of LAHSO, SAS and CTAS).

   Note: *Down-link of LAHSO information "direct" to air traffic would increase airport capacity as well as minimize the need for controllers to apply the aircraft "Group" classifications of Appendix A of FAA Order 7110.65 to all arriving aircraft independent of* **actual** *aircraft landing weight, flap setting, and actual weather / performance considerations.*

5. Down linking of (projected) significant LAHSO speed, configuration, and threshold crossing height (TCH) variances that may preclude safe LAHSO, all direct to air traffic.

6. Down-linking of (projected) minimum fuel state and security information, direct to air traffic.

7. Display of ADS-B ELT "mayday" and other "emergency" type messages for use by controllers and FSS specialists. Example: Single-engine aircraft en route from the Bahamas to Florida -- "Lost power, descending."

   Note: *Data could also be received by other aircraft in the vicinity.*

8. Down-linking requests for alternate airport flight plans due to weather and other in-flight diversions direct to the appropriate controller.

9. Improved / enhanced flight following. Reduced air traffic workload by using real-time / stored ADS-B data in lieu of manually searching for an aircraft when a

pilot fails to close-out a flight plan in a timely manner.

10. **ADIZ penetration and other special use ADS-B messages to NORAD or other appropriate federal / state organizations.**

APPENDIX 3: ANTICIPATED SAS TECHNICAL STANDARDS AND DESIGN GUIDELINES

The following approximately 30 technical standards and design guidelines may be required to "nurture" the SAS process, allowing the private sector to develop and install VFR and IFR certified SAS compatible hardware and software in accordance with the concepts articulated in the SAS "Operational Vision" document and in the Flight Operations and Air Traffic Management (FTMI) Mission Need Statement (MNS). This particular appendix delineates a list of minimum standards. It should be noted that some of these standard writing activities are already underway or even completed. Consequently, an early follow-on effort will be to revise this list into a more accurate and complete document. Once done, to effect the accomplishment of the remaining standards the FAA may draft an omnibus "Terms of Reference" letter appropriate standards writing organization(s): RTCA, SAE, or the Interagency Air Cartographic Committee (IACC). This would start the certification process and would lead to the development of new avionics equipment and flight standards. (See "FAA Certification Process", Figure 3-1, below). The bottom line -- the entire aviation community would participate in defining these standards.

Figure 3 - 1

FAA Certification Process

Need is Determined for New Avionics Equipment	Submitted to RTCA by FAA, Air Carriers, Etc
RTCA Develops MOPS	Published in RTCA Document
FAA (AIR) Develops TSO With Technical Requirements	Published as FAA Document, Invokes MOPS as reference
FAA (AIR) Develops Advisory Circular With Installation Requirements	Published as FAA Advisory Circulars
Avionics Manufacturer Builds Unit and Requests Certification	Manufacturer sends letter with request to the FAA (ACO)
FAA (ACO) Certifies Unit Meets TSO	FAA (ACO) sends letter of certification to the manufacturer
Operator Installs TSO'd Unit and Requests Aircraft Certification	Operator (often the avionics manufacturer) submits a form to the FAA (ACO)
FAA (ACO) Certifies Initial Installation. FAA (FSDO) May Certify Certain Follow-ons	FAA (ACO) issues STC to applicant or FAA (FSDO) issues Form 337 to applicant
FAA (AFS) Certifies Operator; Authorizes the Operation; Amends Operating Specifications (if necessary)	FAA (AFS) sends letter of authorization to the Operator FAA Issues Amendments to Operating Specifications

AFS: FAA Flight Standards Organization, Washington Headquarters
ACO: FAA Regional Certification Office
FSDO: FAA Regional Flight Standards Office

SAS HUMAN FACTORS:

1. Standards defining the critical SAS cockpit human factors functional requirements, including defining an SAS Graphical User Interface (GUI) along with recommended / desired features such as multi-tasking, to bring up background data in the event of an abnormal / emergency condition. This is considered a pivotal design standard as it would define, from a human factors perspective, the overall SAS "cockpit work station" / 2nd generation glass cockpit display system. Additionally, as part of this system integration, the next generation FMS / flight navigator would also be programmed / managed through the interactive SAS display.

2. A "Tunnel-in-the-sky" / "Pathway-in-the-sky" presentation standard that would focus on how best to present en route and terminal area guidance and terrain data to the pilot in an advanced "glass" cockpit display.

3. Standards for human-computer interactive controls. (e.g., touch screens, keypads, trackballs, thumb controls, or voice actuated modules.)

4. Standards for displaying (in both textual or graphical format) air traffic clearances and instructions via data link.

5. Standards for displaying both textual and graphical weather products.

6. Standards for voice recognition commands to program / manage the SAS / FMS / flight navigator system.

7. A human factors design guidelines compendium for use by designers wanting to build SAS compatible systems.

8. Standards for PC based SAS training modules including flight standards and procedures for initial and recurrent flight training.

9. Enhanced pilot decision making (PDM) -- Develop flight training standards and procedures along with tailored hardware / software to ensure adequate levels of performance in an automated cockpit environment.

SAS DATA BASE STANDARDS:

1. Define GPS charting coordinate standards for use in SAS related applications. (The specific issue is whether the SAS system should be latitude / longitude coordinate or Cartesian coordinate based).

2. Define symbology standards for electronic data bases, including "layering" standards for topographical "2D" and "3D" electronic terrain data bases.

3. Define standards for "landscape" format IFR charts, including the various approach charts, SIDS and STARS. Also define the "floating waypoint" concept that supports the SAS GPS standardized curvilinear approach concept.

4. Define standards describing the digital electronic terrain data base libraries needed to support SAS applications for both domestic and worldwide operations. (This includes Electronic Library System (ELS) data base standards, including standards for "2D" and "3D" off-route obstruction data files, noise sensitive areas, and related presentations, along with airport specific departure obstruction clearance and hazard data bases.)

5. Airport surface moving map standards, including standards for formatting and displaying in cockpits standardized data linked taxi clearances.

6. Standards for the establishment, storage, distribution, and loading of SAS electronic data bases.

7. Standards for programming a PCMCIA card for voice recognition purposes.

8. Standards for the storage (in non-volatile memory) of SAS aircraft and external environment situational data (e.g., ATC assigned clearances / instructions) for post-flight retrieval and analysis. (This would provide "source" data for accident / incident investigations as well as company FOQAP activities).

DATA LINK FOR SAS:

1. A standard for GPS ADS-B from which to create a "family" of four TSD compatible systems. This standard should include TSO requirements for the air traffic use of ADS-B. (See Appendix 4, "SAS Data Link Issues").

2. Definition of a ground-to-air data link standard for both textual and graphical weather products. (See, also, Appendix 4, "SAS Data Link Issues").

3. Standards for disseminating aircraft collected "Auto-PIREPS" data from aircraft.

4. Data link standards for communicating both textual and graphical format air traffic clearances and instructions.

5. Standards for a more austere Air Mobile Satellite Service (AMSS) using cellular based technology. Intent would be to allow cockpit access (via cellular phone technology) to public switch networks for use as an emergency back-up for lost VHF communications or for pilot personal use.

6. Standards for other SAS related data link requirements such as data to be exchanged for the surface movement application and wake vortex visualization. (See Appendix 8, "SAS Operational Data Link Requirements").

7. Standards for VHF Digital Data Link (VDL).

SAS CERTIFICATION and CONTINUED AIRWORTHINESS:

1. Standards for SAS modular hardware / software elements which would promote an "open system standard" / open SAS systems architecture.

2. Standards for the certification of VFR use only portable and installed systems, including what would constitute "mission critical" hardware (such as ADS-B antenna installations) which would require more rigorous certification.

3. Standards and practices covering the certification and installation of SAS systems, including any special field installation, approval, and continued airworthiness issues, such as periodic inspection requirements.

4. Standards for certification of low-cost GPS multi-function display technology.

5. "Plug-and-Play" hardware and software "interface" standards. These standards would allow hardware / software manufacturers to efficiently develop safe and affordable SAS applications in a standardized graphical format to meet specific user segment needs while, at the same time, benefiting from the efficiencies of a standardized across-the-board "open" systems architecture.

FANG / SAS CERTIFICATION:

1. Standards to interface SAS system hardware / software with the next generation FMS / flight navigator system.

2. Appropriate instrument approach standards (and supporting air traffic procedures) to define the "floating waypoint" GPS curvilinear instrument approach and thus the supporting FANG / SAS software integration.

INTERNATIONAL HARMONIZATION:

Coordinate all of the above standards, at a minimum, with the international community to ensure international standardization of SAS technologies. These standards will need to be ultimately be incorporated into appropriate Standards and Recommended Practices (SARPs) and associated guidance material of the International Civil Aviation Organization (ICAO).

OTHER STANDARDS AND SPECIFICATIONS:

1. Specifications and standards, as necessary, for ground-based ADS-B (and other broadcast data) receivers for use by air traffic control.

2. Specifications for VHF Digital Data Link (VDL) receivers to support the accelerated adoption of VDL technology within the NAS infrastructure.

APPENDIX 4: SAS DATA LINK ISSUES

__Note__: The following technical issues will need to be addressed as part of a detailed analysis leading to the selection of both SAS "air-to-air" data link and weather data link information.

AIR-TO-AIR DATA LINK:

1. What is the "best" data link technique to achieve the "air-to-air" data link requirements of this SAS initiative? (Current candidates include: The Mode-S "long" squitter, "Mode-T", a VHF / TDMA data link, spread spectrum technology (perhaps using some portion of the existing UHF band or even the MLS "C" band spectrum), various "L" band data link schemes, and so on.)

2. Define the required ADS-B systrem, message size, and format structure to meet SAS "cross-link"requirements?

3. Could a battery-powered "transmit only" version with or without adisplay with perhaps only a 2-3 hour max hour usage requirement for certain low-end users ? What would be the power requirements for a portable battery powered unit?)?

4. Assuming ADS-B is used as a basis for the "autonomous" aircraft concept, will there be a Flight Standards or certification hardware / software requirement for two (2) or more independent units for purposes of redundancy? What reliability standards will be required for ADS-B? Will there be a different equipment redundancy needs to meet FAR Part 23 versus Part 25 certification? (Note: FAR 25.1307 presently requires two systems for navigation, so that the failure of one system will not preclude the operation of the other. How relevant is all this to the need for multiple ADS-B systems when accomplishing "free flight"?)

5. Would air traffic's potential use of GPS ADS-B necessitate any additional ADS-B TSO requirements such as for enhanced integrity or accuracy to support air traffic needs? If so, what will these requirements be?

6. Would there be any benefit from using a Cartesian coordinate system versus a latitude / longitude based system from the perspective of a more simplified message format? Are their any other non data link benefits to be derived by adopting a Cartesian

coordinate based system?

WEATHER INFORMATION DATA LINK:

1. What is the "best" data link technique(s) to achieve this capability? Choices include: Analog VHF and / or analog HF, existing VOR VHF up-link, up-link via a commercial FM radio sub carrier, digital VHF, terrestrial cellular, LEO / MEO cellular and GEO request / reply and "party-line" broadcast, satellite wide area broadcast, Mode-S, etc.

2. For weather information data link technique(s) selected will it meet all user requirements at a reasonable cost?

APPENDIX 5: POLICY ISSUES RELATING TO SAS

1 Reach consensus on the ADS-B frequency and format issue for use in conjunction with both SAS and TCAS IV. (RTCA / ICAO standard needed).

2 Should ADS-B be RNP-based?

3 Should TCAS IV become a fully integrated part of SAS or should it remain as a totally separate and independent system, as a "last line of defense"? If this scenario were adopted, SAS technology with its expanded ADS-B functionality would be used to perform "free flight" -- while TCAS IV would be used exclusively as a back-up "safety net".

4 Will Flight Standards require two SAS ADS-B systems for Part 25 equipment to perform "free flight". As a corollary, what system requirements would be levied for Part 23 equipment wanting to perform "free flight"?

5 Can ADS-B and the ELT be integrated to gain efficiencies in initial installation and in periodic inspections?

6 Is there a requirement for FAA's proposed Traffic Information Service??

7 Is the FAA ready to adopt an all GPS-based surveillance system or will the FAA require additional, independent, technical means (such as SSRs) for ground-based position correlation.

8. Is the user community ready to accept a GPS-based navigation system or does it want a multi-source navigation system?

9. Should the government provide electronic moving map charts with a built-in "2D" terrain data base to the public?

10. Can cellular phone technology be used as an acceptable means to accomplish emergency VHF lost comm back-up, weather information data link, and for general aviation pilots to access, in-flight, the public telephone switching network?

11 To what extent should compression software be used to truncate graphical weather products?

13 Whose responsibility is it to provide graphical weather data into the cockpit? If obtained from a private sector source, what should be the role of the FAA and the various

standards writing organizations in defining performance standards for textual and graphical weather products?

APPENDIX 6: SAS HUMAN FACTORS ISSUES

The following human factor and ergonomic issues will need to be addressed as part of this overall SAS initiative:

<u>NOTE</u>: Refer also to the document entitled, "Proposed SAS Work Tasks in Support of Situational Awareness for Safety", dated February 15, 1995.

1. What is the best way to communicate (vs. simply display) weather data during each segment of flight?

2. Under what conditions would the preferred mode of communication be graphically data linked or data file displayed, voice alerted, or data linked textual messages?

3. What types of training is appropriate in assisting pilots on how to interpret the large amounts of new data in the cockpit?

4. What types of training is required for use in an automated cockpit with highly variable levels of activity and workload?

5. Under what conditions will "head-up" display of SAS information be preferred to "head down" display? To what extent will this depend on mission "critical" vs. "mission routine" data?

6. Which information should be allocated to "head-up" displays and which to "head-down" displays to minimize display clutter? How should decluttering algorithms work when more important information needs to be displayed?

7. What are the merits and liabilities of presenting data through a virtual display using lightweight head-mounted TV goggles or using virtual retinal displays/imaging?

8. What techniques are best for prompting the pilot to attend to a source of information (e.g., synthetic speech, 3-D audio cueing, stereo voice cueing for mid-air alerts)?

9. What are the advantages and disadvantages of voice recognition equipment as an alternative to manual keyboard entry of flight and navigational information, especially for helicopter applications? Consider all air carrier and general aviation segments, including rotorcraft?

10. Within the terminal area, under what conditions is ATC voice better than a data linked

message for "mission routine" vs. "mission critical" tasks and for ATC "clearances" vs. ATC "instructions"?

11. Under what conditions would synthesized voice be better than "head-down" displays of conflicting traffic? Under what conditions would the use of laser lights to cue the pilot's attention to conflicting traffic on the windshield be preferred?

12. What techniques are available for determining the precise information requirements for a pilot during a specific phase of flight? Consider specifically the communication "mode-coupling" and "mode-shifts" by the FMS / FNS?

13. What are the best techniques for allowing the pilot to reduce display clutter and use display "layering" most effectively (i.e., multi-tasking in foreground / background)? Under what conditions should an "enable" vs. "disable" function or a "pull-down" graphic user interface be implemented?

14. What are the minimum display size, resolution, and color requirements for a "head-down" display of **traffic** information? What are the minimum display size, resolution, and color requirements for a "head-down" display of **weather** information?

15. What is the best way to achieve a balance between a "head-in-the-cockpit" philosophy for situational awareness and electronic collision avoidance with a "head-outside-the-cockpit" philosophy for visual collision avoidance?

16. What is the optimal combination of text and graphics to display actual air traffic "cleared" route information as well as the actual location of airspace ownership in "4D" airspace (i.e., How do you protect "bubble" airspace in a "free-flight" environment and show potential traffic conflicts to the pilot)?

17. For aircraft equipped with a Flight Management System (FMS) or lower cost Flight Navigation System (FNS), what is the best way to assure crew acknowledgment and acceptance of changes to the original flight plan before the new flight plan is automatically uploaded into the aircraft's FMS / FNS?

18. What display and user common interface standards should be developed to support SAS, to include functional requirements and display symbology standards?

19. To what extent will different elements of the graphical user interface in use in today's PCs (e.g., point and click, graphical icons, track balls, pull-down menus) be functional in a cockpit environment? What options should pilots have for activating and disabling the various options?

20. What display and I/O features should be implemented to reduce the probability of pilot error in an SAS environment (e.g., eliminating navigation keyboard/pad entry errors)?

21. What is the best way to design SAS displays and I/O interface to reduce the

requirement for initial training and (later in one's flying career) retraining in other aircraft?

22. What are the display and I/O characteristics that would make the display most intuitive and easy to scan? Where is the best location for the display?

23. What aspects of pilot decision making are important for fostering SAS? What is the best way to train functional and effective pilot decision making for SAS?

24. What is the best way to assess the pilot's "mental model" of the air traffic situation? What display and I/O characteristics are required to support the pilot's mental model?

25. What aspects of crew resource management (e.g., shared goals, effective communication) are important for SAS, especially for surface movement?

26. What interface features should be designed to minimize the time the pilot has to remove his hands from the flight controls?

27. What are the "dimensions" of potential SAS applications that are most important for the air carrier, commuter, and general aviation pilots? What implications do these dimensions have for the design of the displays and I/O interface?

28. Several sets of guidelines have been developed for designing the human-computer interface. To what extent are these guidelines applicable and in what areas do new guidelines need to be developed for the SAS program?

29. What is the best way to uplink short-term NOTAM's (such as the first 2,000 feet of runway closed for snow removal) and to graphically display this information?

30. What is the best way to present SAS information to the pilot (and to the controller) to assist in Land and Hold Short Operations (LAHSO) (e.g., as a separation aid, as a spacing aid, or both)?

31. Are there trends in aviation violations and accidents (e.g., navigation errors resulting from failure to cross-check charts) that suggest desirable features of the man-machine interface for SAS?

32. How will providing in-cockpit display of traffic and weather information affect the traditional pilot-ATC relationship? What implications does the "free-flight" concept have for the pilot-ATC relationship?

33. What are the functional design requirements for an "off-line" PC-based" training module to support one or more of the SAS applications? What issues need to be addressed in defining training objectives, user characteristics, and evaluation criteria?

34. Define, from a human factors perspective, how a pilot may best alter (and coordinate) a revised flight routing in a " free flight" environment resulting.

35. Determine when and how responsibility for traffic separation can best be shifted from the controller to the pilot and back again within the context of a “free flight “ infrastructure.

36. Do experienced pilots have difficulty in transitioning to automated aircraft? How can the SAS “cockpit work station” / GUI software ease this transition process?

APPENDIX 7: AN OPERATIONAL SYSTEMS VISION OF SITUATIONAL AWARENESS FOR SAFETY (SAS)

INTRODUCTION

The SAS concept is a compilation of user driven operational needs drafted primarily from a "cockpit perspective". These needs flow, in part, from the goals and objectives contained in the FAA Strategic Plan and from other policy guidance material. In this SAS "Operational Vision" of the future, it is assumed that the United States as well as other foreign airspace providers would welcome the opportunity to decommission their Class I Navaids (i.e., VORs, ILS's, and NDBs) as well as transition to a primarily non-radar based Air Traffic Management (ATM) infrastructure. It is anticipated that enhanced cockpit situational awareness will make a profound and significant impact on aviation safety, efficiency, and airspace capacity.

Perhaps even more importantly, the SAS concept provides the advanced flight and information management integration technologies, along with technical and flight standards, including standards for Tactical Conflict Probe (TCP) for GPS ADS-B, that will be necessary to safely enable "free flight" in the GPS era by those aircraft users suitably equipped.

THE SAS OPERATIONS CONCEPT AS A USER DRIVEN SYSTEM

Situational Awareness for Safety (SAS) is about change, and how to manage change when the supporting technologies are rapidly advancing. The opportunity, shared by all of us in the aviation community, is to somehow take advantage of these technologies and harness them, early-on, for our mutual benefit. Suffice it to say that this is a challenge shared by both public and private sectors.

The SAS initiative addresses this challenge. The SAS process actively solicits the participation of airspace users, service providers, and professional and labor organizations associated with the National Airspace System (NAS) in SAS concept definition, definition of functional requirements, and in the selection of desired features. Each will be given an opportunity to ensure that all SAS goals and deliverables are accomplished on time, at or under budget, and with specific accountability. This is especially important since, ultimately, the user may wish to invest in the technology.

WHAT ARE THE FUTURE SAS FLIGHT OPERATIONAL NEEDS?

A need exists for enhanced pilot, controller and dispatcher situational awareness to achieve an optimum level of flight safety, efficiency and airspace capacity. "Dispatcher" situational awareness may also be applicable to certain segments of general aviation.

From an operational perspective, the proposed future SAS system would provide the user with enhanced decision making capability in a user friendly airspace system that is evolving as a result of the use of GPS and data link communications.

WHAT IS SAS?

SAS is a cockpit-oriented operational concept with emphasis on flight standards and procedural applications based on advances in human factors, cognitive pilot decision making, computer and display technology, advances in precision navigation, data link, and aviation weather systems. Simply put, SAS is the exchange and use of GPS position , terrain, weather and other information effectively displayed to pilots, dispatchers, and controllers, to create an environment that promotes more efficient, safe, and free use of airspace. This information exchange will contribute to an environment that will facilitate implementation of the emerging "free flight" concept. The SAS concept is based, to a large degree, on integrating GPS ADS-B based on-board surveillance information with GPS-based navigation and real-time data link communications among pilots, dispatchers, and controllers.

WHAT WILL SAS DO FOR US? WHAT ARE THE BENEFITS?

SAS addresses the operational needs of safety, efficiency and capacity for all airspace users -- general aviation (GA), air carriers, public use aircraft, and the military -- with economical state-of-the-art technologies, aiding air traffic service providers, pilots, and dispatchers.

SAS operational systems concepts will enable user preferred "direct" navigation and altitude selection. Fixed routes and flight levels as we know them today will cease to exist in this futuristic SAS "end state" called "free flight".

SAS operational concepts provide for increased capabilities and flexibilities with pilots, controllers and dispatchers making better / shared operational decisions -- decisions

based on mission needs and company-based cost index considerations, potentially conflicting traffic, significant weather, airport conditions, terrain, equipage and aircraft performance characteristics.

SAS will enhance ATM efficiencies by providing GPS based ADS-B real-time data to controllers during airport surface, terminal and en route operations.

SAS (through the use of GPS ADS-B) will provide air traffic service providers with a new and cost effective surveillance capability that could be used initially as a back-up to and, perhaps ultimately, as a replacement for existing domestic long-range surveillance radars. (Transponders, as we know them today, would be made obsolete by GPS ADS-B). The limited weather data acquisition functions of existing radars would be assumed by other, more advanced weather data acquisition systems such as NEXRAD (WSR-88D), Terminal Doppler Weather Radar (TDWR), the Integrated Terminal Weather System (ITWS), and GOES imagery.

SAS will provide air traffic service providers with a real-time surveillance capability to enable "pseudo" radar separation standards in what is now non-radar airspace, providing coverage from present minimum vectoring altitudes (MVAs), to the surface, as well as on the airport surface. This will significantly increase system capacity and efficiency.

The SAS system supports graphical cockpit presentations required for reduced vertical and lateral separation standards being planned within the context of reduced required navigation performance (RNP). SAS would graphically combine nav sensor information (that meets appropriate RNP criteria) with GPS ADS-B tactical conflict probe (TCP) data and would present this combined navigation and traffic information to the pilot on a single display.

SAS technology provides for "free flight". SAS equipped aircraft would be permitted to proceed with "due regard" with respect to other traffic, ground obstacles, and weather, resulting in significant benefits commensurate with the operator's investment in enabling and installed SAS technologies and procedures -- providing, of course, that pilots participating in "free flight" (just like their present VFR counterparts) are willing to accept this additional pilot-in-command responsibility. Under free flight, advanced sensors (such as synthetic vision) would allow for additional landing minima credit. Additionally, because of the decreased maneuverability of very large aircraft compared with smaller, more maneuverable aircraft, present right-of-way rules would be revisited as most (if not all) aircraft and air vehicles, under this concept, would become cooperative / compatible targets with on-board SAS traffic awareness / avoidance software. The "free flight" concept and the more broad features of the SAS operational system would, of necessity, flow from ICAO guidance. International coordination will therefore be an important and essential part of the overall SAS process.

SAS will provide pilots with a cost effective means to program and monitor the FMS / lower cost flight navigation system (FNS), along with an integrated means to detect and display aircraft and FMS / FNS "fault" errors and "mode" shifts.

As a result of implementing those beneficial SAS applications, pilot deviations resulting from being temporarily disoriented and wandering into certain controlled or special use airspace, landing at the wrong airport or on the wrong runway or taxiway, waypoint insertion errors, and the inability to quickly reprogram existing FMS equipment, will be significantly reduced. SAS offers the potential to reduce accidents attributed to poor navigation, poor tactical decision making, lack of adequate situational awareness, and sub-standard human factors design.

SAS embraces the emerging flight training disciplines of cockpit resource management and pilot decision-making. Proper initial pilot instruction in the basic SAS technologies would be accomplished through part-task PC based instruction. Extensive training on a totally new suite of avionics equipment will no longer be required every time pilots transition to a different make and model. Fundamental to the overall SAS concept is training in an off-line PC based training environment.

SAS is "human-centered" automation intended to implement the FANS concept of CNS / ATM. The SAS operational system will provide appropriate information to the pilot, to the controller, and when applicable, to the dispatcher. allowing all concerned to make better, more balanced, operational decisions leading to increased benefits in terms of flight safety, efficiency and airspace capacity.

HOW DOES SAS WORK?

The SAS "process", working through the various standards writing organizations, will create technical standards and design guidelines needed so that the manufacturing sector can design and produce the next generation cockpit "work station". Hardware and software components will be fully interchangeable and compatible to allow for their modular installation and replacement. The SAS concept will create common human factor functional design standards to facilitate ease of training and operational use. Because the system will be highly intuitive, time for initial training (to proficiency) over conventional "glass cockpit " systems, will be significantly reduced. Use of trackballs, touch screens, a yoke mounted "thumb" control, or voice recognition modules, among other interactive technologies, may make the current keypad an option, not a necessity.

SAS operational concepts are based, to a large degree, on the use of GPS data combined with "layered" visual displays to create enhanced cockpit situational awareness. Several SAS applications will be able to be displayed at the same time, at the option of the pilot, using a technique called "selective layering". Such layered multi-function displays will serve to provide graphical traffic and weather information services -- a concept air traffic services providers have long supported. Even the most basic SAS data management computer and display combination will support "2D" terrain data in conjunction with GPS aircraft position, reducing the risk of controlled flight into terrain (CFIT) accidents.

Larger aircraft will have more advanced "3D" terrain and obstruction hazard displays, including access to on-board, high resolution, airport obstacle analysis data. In essence, SAS operations will be predicated on enhanced situational awareness of actual ATC clearances, along with graphical presentations of traffic, weather, terrain, own-aircraft flight dynamics, and FMS / FNS guidance mode depiction. When combined with advanced pilot decision-making training, pilots will be able to make better, more informed, tactical decisions during all phases of flight.

SAS is a GPS ADS-B based operational system that will broadcast aircraft ID, radio call sign, trajectory and intent, along with other data messages, enabling real-time surveillance and ATM actions such as effective traffic flow management (TFM).

The SAS on-board surveillance / mid-air collision avoidance function will provide a cockpit display of traffic information (TSD) that, in the high-end systems and at the pilot's option, would also show other nearby aircraft's "intent". This latter, advanced SAS surveillance function, would be designed to offer a Tactical Conflict Probe (TCP) capability to the pilot and could significantly contribute to the flexibility of flight operations.

The SAS "family" of operational software applications provides for six groups of functional applications. A comprehensive list of all SAS applications identified to date is contained in Appendix 1, "List of Candidate SAS Applications". These six functional areas are as follows:

- Flight planning and navigation
- In-flight collision awareness and avoidance / on-board surveillance / station keeping
- Weather awareness and textual / graphical NOTAMS via weather information data link
- Other aircraft related applications
- PC based part-task SAS training
- Air Traffic and Flight Service Station (FSS) applications

As part of this SAS "family", a low-cost, "basic" SAS system is envisioned for use by general aviation users. This basic system will consist of up to three "basic" functional applications:

- GPS moving map / NAV display with at least a "2D" terrain data base
- Traffic awareness (with TSD)

- Textual / graphical weather information data link

An "advanced" SAS system is envisioned for any user that wants to take advantage of the functional benefits of one or more of the "advanced" SAS applications. It consists of the basic system described above plus other "user option" SAS applications. Anticipated users of advanced SAS applications include business-use GA, "high-end" corporate GA, air carriers, military and public use aircraft.

TERMINAL AREA APPLICATIONS OF SAS

The concept of "free flight" holds potential for significant capacity and flight operations efficiency improvements. However, advanced terminal flight path management must be developed and integrated into the SAS concept to accommodate an increased, albeit variable, flow of traffic into the terminal area, resulting in an overall increase in system capacity.

The ATM "process" must account for efficiently "collecting" en route traffic flow from "free flight" operations as aircraft approach the terminal area and manage the movement of these aircraft through "3D" or "4D" final approach "fixes" leading to specific runways. To accomplish these objectives, both the WAAS / LAAS and GPS ADS-B technology applications must be developed and synergistically combined with new air traffic procedures and standards.

For ATM to manage the anticipated traffic volume, the following ATM and SAS functional characteristics must be developed, with functionality incorporated into the aircraft's FMS / FNS.

- Multi-dimensional transition flight path(s) from en route airspace transitioning to an initial / final approach "fix". (As part of this SAS concept, a standardized GPS "floating waypoint" curvilinear approach procedure concept has been conceived that would accommodate all user segment needs and, for those aircraft suitably equipped, would provide "coupled" aircraft guidance to an ATM assigned "4D" point-in-space arrival fix.)

- Three or four-dimensional flight path management.

- Separation assurance (station keeping) provided by both ATM and via advanced SAS display systems / automation in cockpit.

The objective of this total "systems approach" will be to meter air traffic to over the equivalent of today's final approach "fix" at a speed and on a final descent profile at a predetermined time. This objective must be met while providing the cockpit crew with real-time graphical traffic / terrain and obstruction hazard situational awareness. In the

event of a missed approach or rejected landing, graphical departure guidance (including airport obstacle analysis data and appropriate ATM coordination) must be effectively accomplished. During this departure phase, engine-out obstruction clearance data must be provided to the flight crew.

HOW MIGHT THE SAS CONCEPT BE IMPLEMENTED?

The basic SAS development and implementation strategy is to allow for ordered introduction of SAS applications while, at the same time, providing incremental benefits to those who are willing to invest in the enabling technologies, procedures and standards, in concert with worldwide development and harmonization.

Low-end" SAS systems (intended for recreational use including aircraft without electrical systems) may be either installed or portable although certain SAS supporting hardware (such as an externally mounted antenna) will need to be permanently installed in the aircraft.

"High-end" general aviation systems (intended for IFR business and corporate aircraft use in aircraft certified to 14 CFR 23 standards) would consist of installed equipment. Affordable retrofit systems, including those for FAR Part 25 certified transport category aircraft with older installed electromechanical displays and with limited panel space, will be a major SAS design objective. (Existing first generation "glass" panel aircraft may only need to make minor modifications to their existing panel displays although supporting SAS hardware and software will be required).

For the larger and more sophisticated transport category aircraft, designed to 14 CFR Part 25 standards, the SAS avionics would be designed to appropriate standards. Reliability and field maintenance will be major design considerations. Additionally, some of the SAS output functions will need to be integrated with existing FMS / autopilot units or the advanced ATM and ATN compatible FMS being functionally developed as part of the broader Flight Operations and Air Traffic Management Integration (FTMI) project. In this use, the SAS and FMS / flight navigator combination would assist the flightcrew in performing "coupled" routine and mission critical operations of the aircraft. Additionally, since all waypoints will be electronically inputted directly into the FMS / flight navigator system (with pilot review and concurrence beforehand), this will reduce if not eliminate the possibility of manual waypoint insertion errors. The next generation FMS (or the lower cost flight navigator system) will be designed to be fully ATM-compatible and will be designed to facilitate air traffic activities with the aid of the emerging ATM data link services.

While several SAS applications do not require and are independent of fleet-wide retrofit, the SAS traffic awareness / collision avoidance / on-board surveillance application, referred to as a "family" of four TCAS IV functionally compatible GPS ADS-B software

packages, will require that a large percentage of both the civil and military fleet be equipped with, at a minimum, a cooperating "transmit only" GPS ADS-B system. This inexpensive and most basic SAS "transmit only" GPS ADS-B system would not need to have any display capability but would merely need to operate as a cooperative GPS ADS-B target. This most "basic" SAS ADS-B system would be available in both battery powered, i.e., portable, and ship-powered versions.

As part of this SAS concept, it is proposed that all aircraft owners, including those who own air vehicles (as defined under 14 CFR Part 103), would receive an economic incentive, i.e., a credit. This credit could then be exchanged for either a "transmit only" SAS system (without a display) or a SAS system with a display and with the basic SAS software applications installed. In this latter "exchange" case, the user would pay only for the net cost difference. While there would be an initial cost to the government for such an initiative, there would be an even significantly greater net cost savings over the long-term as the FAA could then convert to a predominantly non-radar based ATM system embracing the "free flight" concept. Additional cost savings to the government would come from increased safety, efficiency and capacity enhancements emanating from the SAS concept, along with the possible accelerated decommissioning of ground-based Class I Navaids. Still further savings could be realized through the implementation of a standardized GPS approach procedure using aircraft-based terrain and obstacle data files ensuring adequate terrain separation. Even further savings might be achieved by combining the ELT function with ADS-B in a single unit.

Selected SAS functional applications would be implemented in stages. The same is true of associated hardware and software. For example, portable display systems with permanently installed antennas and ADS-B systems, would provide the VFR aviation community with enhanced, new capabilities such as moving map, traffic awareness and weather information, at a minimum cost of installation. The starting point is today's technology (including hardware, software, procedures, and human factors engineering for both high-end and low-end aircraft), most of which can be adapted from existing technological know-how in concert with the operational requirements of the FANS CNS / ATM operational system concepts.

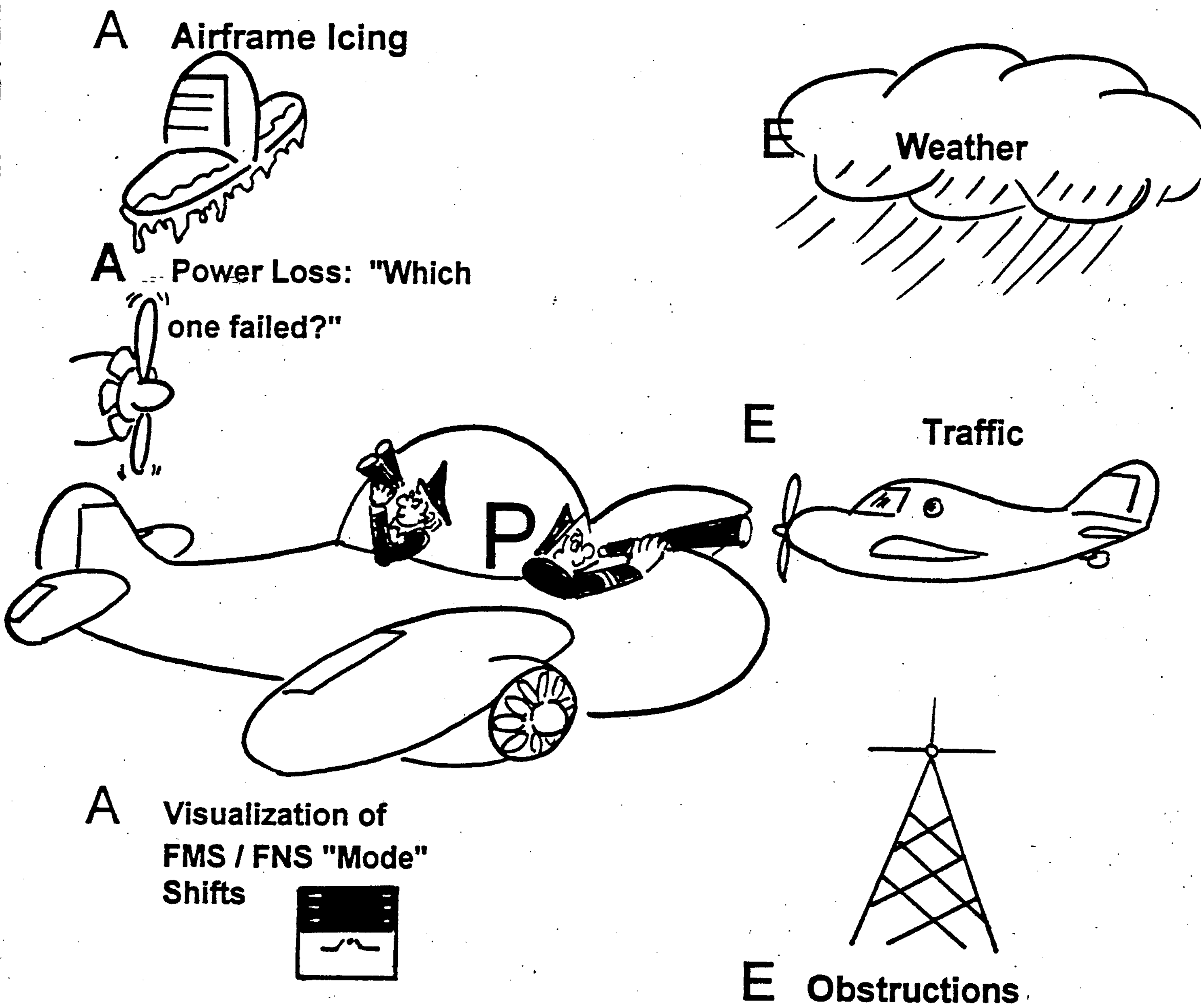
The SAS operational systems vision is depicted in Figures 7-1, 7-2, and 7-3. Appendix 1 contains the "List of Candidate SAS Applications".

<u>ATTACHMENTS</u>:

-- Figures 7-1, 7-2, and 7-3.

FIGURE 7-1

SAS IS COCKPIT-CENTERED SITUATIONAL AWARENESS



<u>Where:</u>

"A" is for "Aircraft" "P" is for "Pilot" "E" is for External "Environment"

<u>Note</u>: Enhanced situational awaréness training for "P" ("pilot") related issues would be addressed through advanced pilot decision making and CRM training.

Figure 7-2

SAS OPERATING ENVIRONMENT

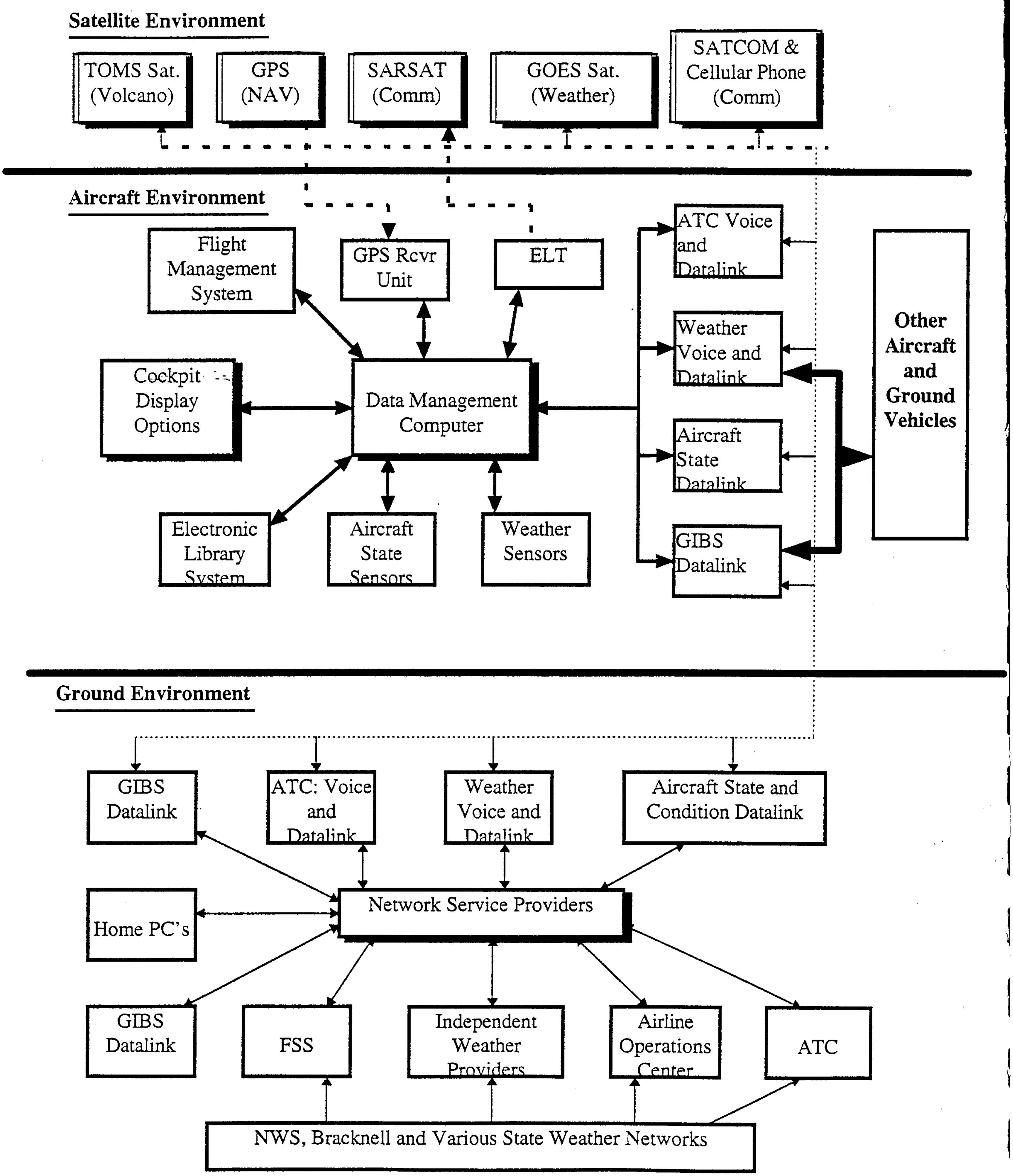
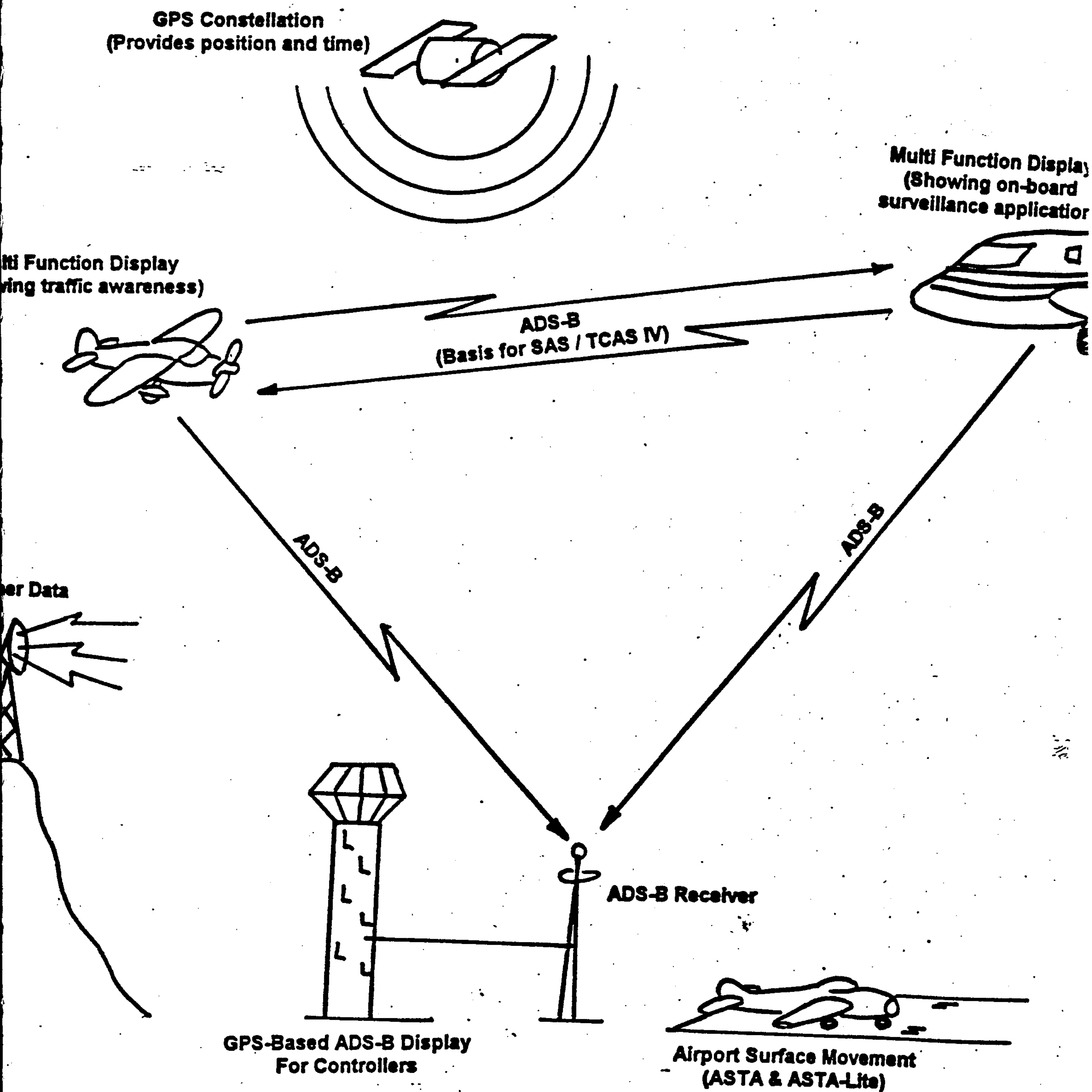


FIGURE 7-3

SAS OPERATIONAL VISION

SHOWING ON-BOARD AND SURFACE SURVEILLANCE APPLICATIONS



APPENDIX 8: SAS OPERATIONAL DATA LINK REQUIREMENTS

Note #1: The following draft list has been prepared from a "cockpit perspective" and addresses what is believed to be the consolidated combined data link needs of the pilot / flight deck, aircraft operations center (AOC), and ATM "provider". Both air carrier and general aviation data link application requirements are commingled in the following list, with some applications already having been addressed as operational requirements in other documents. ***There has been (as yet) no formal effort made to prioritize the following applications nor to accomplish a technical, operational, institutional or economic feasibility or market need analysis.***

Note #2: This appendix deals exclusively with civil needs of SAS data link. Military and other government agency requirements and uses of ADS-B are not included in this paper.

Note #3: Data link definitions used in this appendix are as follows:

> ***Up-link needs:*** *Electronic data transmission from either the AOC, ATM or a third party to an aircraft.*
>
> ***Cross-link needs:*** *Electronic data link exchanges between aircraft in flight, or between aircraft and surface vehicles, or vice versa.*
>
> ***Down-link needs:*** *Electronic data transmission from the aircraft to the AOC, ATM or a third party.*

FLIGHT PLANNING AND NAVIGATION:

1. Integrated preflight planning and way-point insertion into the SAS, GPS based flight navigation system or FMS prior to engine start.

   Up-link needs: Need to obtain a textual and graphical weather / NOTAMS briefing prior to flight. Need to receive flight plan data containing both textual and electronic waypoint data, along with winds and temperatures aloft data, all in digital format, so it can be fed directly into the FMS / flight navigator as well as displayed on the SAS display. This pre-flight planning process can be done either outside or inside the aircraft. If done inside the aircraft, it may be more advantageous to perform it via data link.

   Cross-link needs: None

   Down-link needs: Need to request the above data via use of a software program. The data connect "process" needs to be effected, at the user's option, from either outside the aircraft as well as within the aircraft.

2. Intuitive, user friendly, in-flight re-planning / re-programming capability (along with the appropriate AOC / dispatch / flight following tie-in).

   Up-link needs: The AOC (or its FAR Parts 91 and 135 non-regulatory equivalent) needs to provide suggested flight plan data revisions to the cockpit for review. Flight plan needs to be available for display both textual and graphically. ATM also needs to be able to send (as needed) "official" air traffic re-routes to aircraft. "Official" ATM flight plan then needs to be displayed in graphical as well as textual format. Flight plan also needs to be in electronic format suitable for loading directly into the FMS / flight navigator

   Cross-link needs: None

   Down-link needs: Aircraft needs to communicate via data link direct to AOC and ATM to resolve any issues surrounding alternate destinations and re-routing. In the case of a weather diversion following a missed approach, the crew normally resolves this directly with the departure controller as to where to hold / proceed and what would be the nearest alternate airport. In the SAS concept, this could be done via data link once the pilot inputted the requested revised routing via the interactive SAS display, i.e., by touch screen, thumb button, track ball, VRE, etc.

3. Graphical display of "active" special use airspace (SUA).

Up-link needs: ATM must be able to up-link SUA activity data to the ELS immediately prior to and during flight

Cross-link needs: None

Down-link needs: None

4. ATC assigned clearances and instructions (in both textual and graphical format).

Up-link needs: ATM needs to be able to send both textual and graphical compatible clearances and instructions to aircraft. ATM data must also be formatted for direct digital loading into the FMS / flight navigator system.

Cross-link needs: None

Down-link needs: Aircraft need to be able to acknowledge receipt of all ATM messages using a standardized lexicon to effect this data link communications exchange. Key words include: "accept", "reject", or "need to negotiate". International standardization of this data link "language" is essential to preclude any misunderstandings, especially with crews that may not fluently speak, read or write in English.

5. Graphical display of ATM assigned instrument approaches showing terrain, obstruction hazards, and other ATM assigned restrictions.

Up-link needs: ATM must assign clearances in SAS / FANG compatible format. See Item # 4, above. Any non-standard MAP instructions must also be included as part of this message "string" requirement. (Note: As part of the conceptual development of a single, standardized "floating waypoint" GPS curvilinear approach procedure, certain additional data will need to be provided to the aircraft to be used in calculating its descent profile. Specific data may include winds and temperatures in the terminal area from the surface to 10,000 feet AGL, convective weather "VIP levels", "layers" (in terms of "blocks" of altitude) where icing is reported or forecast as "moderate to severe", along with noise "footprint" restrictions based on real-time day / night sound level (DNL) measurements, among others).

Cross-link needs: None

Down-link needs: Aircraft must be able to acknowledge the clearance and any supplemental instructions via voice and / or data link.

6. Graphical display of missed approach, rejected landing, and standard instrument departure procedures.

   Up-link needs: Any ATM assigned rejected landing instructions must be communicated in a format suitable for direct (and immediate) entry into the SAS system as well as the FMS / flight navigator system, if installed. This need includes textual, graphical, as well as FMS / FNS compatible messages.

   Cross-link needs: None

   Down-link needs: Aircraft need to be able to acknowledge all clearances. In the event of one-engine inoperative or another emergency, aircraft must be able to send that "condition" notice to ATM by priority data link message.

7. A cockpit display of airport surface movement activity along with a graphical display of all ATM assigned taxi clearances / instructions, plus display of all required hold short points.

   Up-link needs: ATM needs to send textual / graphical ATM clearances and specific taxi instructions via data link, including highlighting specific hold short points / clearance limits. Format must allow direct input into FMS / flight navigator. Clearances need to be formatted to allow the SAS display to graphically display all active runways as well as assigned hold short points. Additional ATM traffic management data include: push-back time (if at gate), departure runway, and anticipated takeoff time.

   Cross-link needs: None except that the intent of other conflicting aircraft taking off and / or taxiing need to be shared. (See Item # 2 under "In-flight and Airport Surface Collision Awareness...", which follows, for specifics).

   Down-link needs: Aircraft need to be able to acknowledge all ATM assignments.

8. A visual display (when airborne) of the airport and airport runway combination to assist in landing at the proper airport, assigned runway, and to provide TSD situational awareness / "station keeping" for parallel or converging runway approaches.

   Up-link needs: For controlled airports, ATM needs to up-link active runway-in-use (and active approach corridors) so this data can be displayed as background on the ELS generated airport diagram. When part of a runway is closed, or there is a displayed threshold, that data also needs to be sent and **graphically** presented to the pilot on the SAS display.

Cross-link needs: Aircraft on approach to any runway (but especially converging or intercepting runways) need to have their position shown in relation to the other aircraft as well as to display both runways and approach corridors that are active. (At uncontrolled airports, the ADS-B position of other aircraft will be graphically superimposed on the recommended traffic pattern silhouette for that airport, including a notation as to TPA).

Down-link needs: None

IN-FLIGHT AND AIRPORT SURFACE COLLISION AWARENESS AND AVOIDANCE / ON-BOARD SURVEILLANCE / STATION KEEPING:

1. In-flight traffic information and on-board surveillance using a Traffic Situation Display (TSD) including Tactical Conflict Probe (TCP). Both the aircraft and the ground would share the same real-time data. There would be a "family" of four GPS based ADS-B systems as follows:

    - ADS-B "transmit only" system without SAS display

      Up-link needs: None

      Cross-link needs: ADS-B would broadcast GPS derived position data, aircraft / air vehicle assigned 24-digit ident #, along with the aircraft's assigned "radio call sign".

      Down-link needs: ATM can listen if within LOS. There would be no capability for this unit to receive any ATM messages.

    - "Basic" ADS-B traffic awareness, i.e., traffic advisories only

      Up-link needs: None. (Note: ATM could attempt to contact this aircraft "in-the-blind" once the aircraft's ID was known to air traffic).

      Cross-link needs: ADS-B needs to broadcast the GPS derived position and time data, 24-digit aircraft ID (from which other aircraft and ATC could use their ELS / data base to determine specific make / model), the aircraft's assigned "radio call sign", along with the other aircraft's next FMS / flight navigator waypoint "intent" data (and / or altitude and VSI pre-select data) if available for broadcast, whether the aircraft had received the

other aircraft's ADS-B message and, if so, whether the other aircraft was initiating an "escape" maneuver and in which direction.

__Comment__: Altitude "pre-select" permits capture of a pre-selected altitude during climb or descent plus vertical speed to that selected altitude.

Down-link needs: ATM can listen if within LOS.

- ADS-B collision avoidance, i.e., TA's and RA's for vertical as well as horizontal maneuvers, that is, **full** TCAS IV functionality

  Up-link needs: None. (Note: ATM could contact this aircraft "in-the-blind" once the aircraft's ID was known)

  Cross-link needs: ADS-B needs to exchange GPS derived position data, 24-digit aircraft ID (from which other aircraft and ATC could use their ELS / data base to determine make / model), the aircraft's assigned "radio call sign", along with the other aircraft's next FMS / flight navigator waypoint "intent" data (and / or altitude and VSI pre-select data) if available for broadcast, whether the aircraft had received the other aircraft's ADS-B message and, if so, whether the other aircraft was initiating an "escape" maneuver and in which direction.

  Down-link needs: ATM can listen if within LOS. The aircraft may need, if required by air traffic, to transmit a message that a "RA" was in progress, along with an indication as to what "escape" maneuver was being conducted, and in which direction.

- ADS-B collision avoidance with on-board surveillance capability, i.e., TCAS IV functionality with FMS integration and / or altitude / VSI pre-select (i.e., TA's, RA's, and Tactical Conflict Probe (TCP) capability)

  Up-link needs: None. (Note: ATM could contact this aircraft "in-the-blind" once the aircraft's ID was known)

  Cross-link needs: ADS-B needs to exchange / broadcast GPS derived position data, 24-digit aircraft ID (from which other aircraft and ATC could use their ELS / data base to determine make / model), the aircraft's assigned "radio call sign", along with the other aircraft's next FMS / flight navigator waypoint "intent" data (and / or altitude and VSI pre-select data) if available for broadcast, whether the aircraft had received the other aircraft's ADS-B message and, if so, whether the other aircraft was initiating an "escape" maneuver and in which direction.

Note: In designing this system plan on the possible requirement for two separate GPS ADS-B systems (with TCP) to allow for adequate system redundancy and to permit "free flight" operations for those aircraft that must maintain the highest levels of safety.

Down-link needs: ATM can listen if within LOS. The aircraft may need, if required by air traffic, to transmit a message that a "RA" was in progress, along with an indication as to what "escape" maneuver was being conducted, and in which direction.

2. Airport surface movement traffic awareness and collision avoidance along with "station-keeping" during taxi / push-back operations.

Up-link needs: none.

Cross-link needs: This application would be used at both controlled as well as non-controlled airports, including movement, non-movement and ramp control areas. ADS-B would broadcast GPS derived position data, 24-digit aircraft ID (from which other aircraft could use their ELS / data base to determine make / model), the aircraft's assigned radio call sign, and next FMS / flight navigator "intent" data for auto taxi (especially useful during very low IFR / SMGCS type operations). A user generated need may exists to transmit aircraft fuselage heading alignment so that, while in the SAS "zoom" / close-in setting, pilots can ensure adequate wing-tip to wing-tip separation, thereby reducing the requirement for wing walkers.

Down-link needs: ATM can listen if within LOS or if received by a remote ADS-B receiver with a tie-in to the controlling TRACON. (Note: At non-controlled airports or at low activity controlled airports, ATM effectively obtains an limited functionality "ASTA-Lite" capability without the capital investment associated with ASTA).

3. Graphical display of ground-based man-made obstruction hazards.

Up-link needs: A battery-powered / ground-based powered ADS-B transmitter only unit would transmit position and height hazard data of temporary obstructions until such time as they were charted and made available to the ELS.

Cross-link needs: AF and ATM would need to know if and when this device ever became OTS.

Down-link needs: None

4. Graphical display of military training routes (MTRs) as well as military aircraft operating along MTRs and within SUA.

   Up-link needs: None

   Cross-link needs: Military aircraft need to broadcast their GPS derived position data along with what VR / IR route they were operating on plus their next intended change in altitude. Their aircraft's 24-digit ID data (from which other aircraft could derive make / model) could be enabled / disabled by the PIC to meet defense and other security requirements. (The SAS display would then display aircraft position and movement direction along with highlighting the intended route / SUA boundary).

   Down-link needs: None

WEATHER AWARENESS AND NOTAMS VIA DATA LINK:

1. Graphical and textural depiction of pre-departure, en route and terminal area weather.

   Up-link needs: Weather reports, forecasts, GOES imagery, composite radar data, ITWS, TDWR data, etc., needs to be provided to the cockpit in textual / graphical format in a timely, almost real-time basis. (This may mean that error free transmission rates in excess of 10-20 Kbps need to be used along with a minimal use of compression techniques). Means to accomplish this dissemination of weather data include local and wide area broadcast as well as request / reply. A public policy issue that needs to be resolved is whether the government or private sector will provide these data and at what cost to the user? (Note: There is also an unsubstantiated technical possibility that "3D" DTED / DVOD terrain and obstruction data might be up-linked to aircraft as part of a local area broadcast of weather information. This technical issue has been identified as one that will need to be addressed through a separate study / analysis).

   Cross-link needs: None except that the AOC, ATM and aircraft must have contemporaneous access to the identical weather products, with the AOC able to discuss (by voice / data link) strategic and tactical flight planning / re-dispatch issues with the flight crew.

   Down-link needs: Aircraft will need to be able to request specific products or, using the on-board GPS clock, access a continuous broadcast message at the proper time to download the needed data.

2. Graphical display of volcanic ash information.

Up-link needs: This would be a combined report / forecast, in graphical format. These data needs to be made available for operations in both domestic and oceanic airspace (especially in the Pacific Rim basin) on a priority basis. (See Item # 1, above).

Cross-link needs: None

Down-link needs: Aircraft will need to be able to request this specific product.

3. FMS / flight navigator winds, temperature, and other data fields. (This specific weather-related application is needed early-on to support the "Standardized 'Floating Waypoint' GPS Curvilinear Approach concept.)

Up-link needs: ATM / AOC will need to provide these data fields in digital format for direct FMS / flight navigator input during pre-flight FMS initialization and to up-date them during en route operations. Additionally, there is an emerging user need for real-time winds in the terminal area, say below 10,000 AGL, "VIP" levels, and "layers" of moderate / severe icing to support SAS "best time" to the airport calculations (this to minimize total trip time). The requirement for these additional data needs to be evaluated in conjunction with the possible development of the standardized "floating waypoint" GPS curvilinear instrument approach concept. Refer to the draft paper entitled, "A Proposal For a Standardized "Floating Waypoint" GPS Curvilinear Instrument Approach Procedure" for additional details.

Cross-link needs: None

Down-link needs: Aircraft will need to be able to request these specific products including data for above and below their initially planned for altitude.

4. Graphical presentation of the winds on final approach including touchdown zone surface winds (all via real-time data link).

Up-link needs: Real-time surface winds at each runway threshold (not center field or other airport winds) need to be automatically and continuously sent to the aircraft in digital format.

Cross-link needs: None

Down-link needs: None

5. Graphical cockpit display / visualization of wake vortex hazards.

   General Comment: *This application needs further technical validation but, if feasible, may have a major impact on safety and airport capacity.*

   Up-link needs: Ground based wake vortex correction data, i.e., wind and ground truth corrections within the Earth's boundary layer, may (but at only the busier airports) need to be up-linked to aircraft within 10 miles or so of the airport. This data link requirement must include "low-end" general aviation aircraft in a cost effective solution as they are most susceptible to these wake vortex hazards.

   Cross-link needs: Aircraft at altitudes below 10,000 feet AGL need to exchange, in addition to the "standard" GPS ADS-B based surveillance data, information on their landing weight, their gear up or down configuration, and flap setting, with other aircraft nearby. (Note: It may also be advantageous for those aircraft on final approach to exchange GPS derived wind data with other nearby aircraft. This may prove useful to allow other aircraft to intercept and stay aligned on the final approach segment as well as to anticipate possible wind shear on final).

   Down-link needs: None

6. Auto-PIREP "down linking" and "cross-linking" (if within LOS) of selected in-flight weather.

   Up-link needs: None with the possible exception that a ground-based automatic "repeater" station could be used to take "air-to-air" cross-link weather data, record it on a telephone-like answering machine, then have it available for playback when requested by an aircraft that was within LOS. Such a capability would help (but might not completely solve) the challenge of providing winds and temperatures aloft data to aircraft landing at airports that were not equipped with more sophisticated upper air measuring devices. The "floating waypoint" GPS approach concept could specifically benefit from this data link application.

   Cross-link needs: Aircraft would passively "listen" to these down linked PIREP messages, and can thus exchange certain weather related "state" information among other aircraft within LOS, such as OAT, turbulence levels, in-flight icing data, actual winds and turbulence data, bases and top reports. etc. This function will be especially helpful for aircraft "in the weather" at the lower altitudes and while on approach.

   Down-link needs: This "Auto-PIREP" data would also be sent to the NWS and

ATM for input into their PIREP collection process and for use in weather forecasting, especially "nowcasts".

7. Cockpit display of textual and graphical NOTAMS including graphical visualization of temporarily and permanently displaced runway thresholds, closed runways and closed taxiways.

   Up-link needs: Real-time NOTAM data needs to be provided to the cockpit. (All NOTAM data, if appropriate, needs to be in a format suitable for graphical presentation on the SAS display). For instance, if snowplowing operations close the first 2,000 feet of a runway, the airport diagram displayed on the SAS display should be graphically marked to clearly show that the first 2,000 feet of the runway is closed. Current NOTAMS for a particular airport or NOTAMS covering en route conditions, special NOTAMS, as well as ALL published textual and graphical NOTAMS, need to be available in an electronic data file, and available to the cockpit, on a request / reply basis.

   Cross-link needs: None

   Down-link needs: None

8. Display of digitized ATIS to flight crews.

   Up-link needs: Digitized ATIS must be available to the cockpit in both textual and, as appropriate, in graphical format as well. (Note: This is an immediate requirement regardless of development and status of SAS. It specifically impacts those high flight activity "corridor" shuttle operations which are "up / down" and where crews have extremely limited time to write down the ATIS / NOTAMS currently provided crews in voice only ATIS format). Digital ATIS would be a continuous broadcast available when within LOS.

   Cross-link needs: None

   Down-link needs: None except that the aircraft will need to acknowledge error free receipt of the most current digital ATIS.

9. The SAS on-board computer / display system would convert data link provided runway braking friction values (i.e., Mu data) to landing and takeoff stopping distance requirements, i.e., takeoff and landing accelerate / stop distances.

   Up-link needs: ATM needs to provide real-time MU data to the cockpit when conditions warrant whenever the aircraft is operating within the terminal area for

purposes of taking off or landing.

Cross-link needs: None

Down-link needs: None

OTHER AIRCRAFT RELATED APPLICATIONS:

1. In-trail climb, descent, or passing maneuvers in oceanic airspace. (As precursor to an end-state called oceanic "free flight").

   Up-link needs: None (except that in the initial stages, ATM would be requested to issue a clearance for the maneuver beforehand through use of oceanic data link and GPS position). In the end-state, ATM need only acknowledge that the maneuver had taken place.

   Cross-link needs: ADS-B needs to broadcast GPS position and time data, aircraft ID, and next FMS planned waypoint. Aircraft would use the Tactical Conflict Probe logic to assess potential conflicts and to alter course as necessary. (TCP is the basis for aircraft based separation assurance and "free flight" capability). Since there may be a requirement, for reasons of reliability, for two independent ADS-B systems in oceanic airspace, this dual equipment requirement needs to be considered in the final selection process for ADS-B to support "free flight".

   Down-link needs: In the initial stages of oceanic passing maneuvers using ADS-B, an ATM clearance to execute the maneuver would be requested beforehand. In the SAS / ADS-B "end-state", aircraft would merely advise ATM via oceanic data link that a maneuver had been completed.

2. In-trail climb, descent, or passing maneuvers in domestic en route and extended terminal airspace. (End-state is called domestic "free flight").

   Up-link needs: None (except that in the initial stages, ATM would be requested to issue a clearance for the maneuver beforehand through use of data link. In the end-state, ATM will need to only acknowledge that the maneuver had taken place.)

   Cross-link needs: ADS-B needs to broadcast GPS position data, aircraft ID, and next FMS planned waypoint. Aircraft would use the Tactical Conflict Probe logic to assess conflict potential and to alter course as necessary. (TCP is the basis for

aircraft based separation assurance and "free flight" capability). Since there may be a requirement, for reasons of reliability, for two independent ADS-B systems in domestic airspace (especially since there also would be no SRR coverage as conceptualized in the SAS Operational Vision; see Appendix 7); this dual equipment requirement needs to be considered in the final selection process for ADS-B, especially when it is supporting "free flight".

Down-link needs: In the initial stages of domestic passing maneuvers, ATM clearance to execute the maneuver would be requested beforehand. In the SAS / ADS-B final "end-state", aircraft would merely advise ATM that a maneuver is in progress or that it had been completed.

3. In-trail spacing in oceanic and domestic en route airspace and / or on final approach (i.e., separation by distance and / or by speed). Also, manually flown or FMS managed station keeping

   Up-link needs: Normally no requirements except that ATM could assign a specific distance to be maintained for whatever reason. (It is anticipated that flight standards would establish, for reasons of safety, minimal ADS-B separation distances, with appropriate credit for wake vortex visualization software, to be adhered to by all pilots).

   Cross-link needs: All participating aircraft would need to exchange ADS-B messages including FMS / flight navigator next waypoint "intent" data. Full-time display of these data is essential to ensure safety and to effect cockpit display of traffic information.

   Down-link needs: None except that ATM would have the opportunity to monitor separation distances to ensure that appropriate safe separation standards are maintained.

4. Electronic aircraft "status" / condition monitoring, data collection and down link reporting.

   Up-link needs: Probably none. (Data sets would be transmitted to a ground facility on an "as programmed" automatic basis or, at the user's discretion, on a request / reply basis.)

   Cross-link needs: None

   Down-link needs: Data sets requirements would be identified by the operator (or airframe / engine / appliance manufacturer) and would be periodically down linked

to the AOC or other designated party for review and analysis as needed.

5. GPS based ELTs. (Distress and other emergency messages would also be sent in-flight when possible and within LOS on the appropriate data link frequency. Additionally, some have suggested that the ELT and ADS-B units be physically combined into one functional unit to gain certain efficiencies of installation and inspection).

   Up-link needs: None

   Cross-link needs: The data link message would convey that a "mayday" / incident / accident / emergency was in progress or about to happen. The pilot would have the capability to manually initiate the "transmit process" in the event of an emergency. Data link would be LOS limited and, if activated while airborne, would have a wide area of coverage and could thus be received by all aircraft that were within LOS.

   Down-link needs: The data link message needs to be received by all appropriately equipped ground stations within LOS (e.g., ATM, AFSS / FSS, ARINC, etc.) as well as via SARSAT data link (408 MHz). Data message format should include GPS based position, time of occurrence, and aircraft ID.

6. Air-to-ground "voice" communications using cellular phone technology as an emergency back-up to VHF communications or for pilot personal use applications. (Standards would allow cockpit access to public switch telephone networks).

   Up-link needs: As needed by the calling party.

   Cross-link needs: None

   Down-link needs: As needed by the pilot and / or passengers. (Note: There is considerable interest in using cellular technology, either terrestrial or space-based, to accomplish the weather information data link application in lieu of or in addition to any government provided services that may evolve).

AIR TRAFFIC AND FLIGHT SERVICE STATION (FSS) APPLICATIONS:

***<u>Note:</u>* The following are only possibilities. They have not been formally accepted as validated requirements or services.**

1. AOC-ATM ground interchange of data

Up-link needs: N/A

Cross-link needs: Ability to freely exchange voice and data from AOC to ATM and visa versa. This is both a world-wide as well as domestic requirement. Users need a greater say in establishing priorities for ATM operations predicated on user based cost indexing and other operational needs.

Down-link needs: N/A

2. Air traffic clearances, instructions, textual and graphical NOTAMS up-link to aircraft. This includes transmitting of standardized (or uniquely assigned) taxi clearances and instructions to aircraft operating on controlled airports.

Up-link needs: As required by ATM. Additionally, there should be a means to send an ATM message to a data linked equipped aircraft that is in ADS-B contact with air traffic but has yet to establish either voice or data link contact.

Cross-link needs: None

Down-link needs: The pilot has the need to acknowledge receipt of all clearances / instructions as well as the requirement to exercise PIC authority to review the request and either accept, reject, or negotiate a mutually acceptable alternative course of action.

3. Controller display of in-flight aircraft position based on ADS-B data along with FMS programmed "intent" when available. This application could be expanded to also include (which will be part of the initial SAS application / validation efforts) ADS-B reception at a remote airport with tie-in to the controlling AT facility, thereby permitting AT to apply radar separation standards in airspace that presently does not have radar coverage.

FYI: *This specific SAS application should be targeted to cover both domestic (including Alaska and Hawaii) and Gulf of Mexico airspace. By installing ADS-B sensors on the ground, this application has the potential to allow for much greater use of radar separation standards in what is presently non-radar airspace.*

Up-link needs: None

Cross-link needs: None

Down-link needs: ATM would be in a passive mode, listening, and monitoring operations for purposes of flow control and national security. In the event of a TCAS "RA" type maneuver, it is understood that controllers would need to know that an "RA" was in progress, and the actions taken. (These requirements needs to be translated into specific message format requirements at the direction of air traffic management, and with input from user and labor interests).

4. Controller display of airport surface movement activity and aircraft conformity with ATC assigned taxi and takeoff clearances, i.e., ASTA and ASTA-"Lite".

   Up-link needs: None

   Cross-link needs: Aircraft need to know the ADS-B position of other aircraft operating on the surface, including in the ramp area, non movement areas, and movement areas. Additionally, aircraft while on final approach need to have their position displayed on the SAS cockpit display of those aircraft operating on the surface if they are about to enter onto the active runway. Also, if an aircraft is about to take-off, or is in the process of taking off, that event needs to be communicated to the cockpit of the aircraft on final.

   Down-link needs: ATM needs to receive the GPS position and, if applicable, the FMS / flight navigator taxi- / takeoff-"intent" data of each aircraft operating on the surface and within the movement area. (Note that this requirement is less restrictive than the aircraft-based application which requires highly accurate data in the movement, non movement and company controlled ramp areas.)

5. ADS-B based controller display of precision parallel runway alignment / monitoring. Tie-in with the Precision Runway Monitoring (PRM) effort.

   Up-link needs: None

   Cross-link needs: Aircraft conducting parallel and converging approaches need to know the position of other aircraft as well as their "intent".

   Down-link needs: ATM needs to know the GPS ADS-B derived position and time data from which to conduct ATM based tactical conflict probe analyses and traffic management in the terminal area. (In most cases, the PRM can be eliminated or can serve as a back-up system to the ADS-B display).

6. Controller display of down linked aircraft approach speeds (for spacing) and actual factored AFM data distance requirements (for LAHSO). Also, down linking of

significant LAHSO speed, configuration, and threshold crossing height (TCH) variances that would preclude safe LAHSO, along with minimum fuel state and security information, all direct to air traffic.

Up-link needs: The arriving aircraft (when within LOS distance of the airport) needs to receive a digital message of runway temperature and landing threshold winds.

Cross-link needs: None except that the other participating aircraft's position and "intent" must be continuously displayed on each participating aircraft's SAS display.

Down-link needs: As the aircraft enters the terminal area, ATM needs to receive the aircraft's **landing distance requirements** as calculated by the aircraft's on-board SAS computer using "pull-down" aircraft performance files stored in memory within the ELS. Then, after being cleared to land to hold short, at a distance from the runway (perhaps at the glide path intercept point), the aircraft would again recompute its LAHSO distance requirements based on actual speed, actual configuration, and any variance in altitude anticipated (from nominal) when crossing the threshold, and would advise air traffic if the approach was within projected tolerance / safety limits or whether the clearance had to be canceled and / or amended. All air traffic will need to know is the landing distance needs of the inbound aircraft. (How this information is communicated to the controller is a separate issue).

7. Display of ADS-B ELT "mayday" and other kinds of "emergency" messages (activated manually by the pilot or automatically after an accident) for use by controllers and FSS specialists. (Note: Data would also be received by other aircraft in the vicinity. See Item # 5 under "Other Aircraft Related Applications").

Up-link needs: None

Cross-link needs: A combined ADS-B / ELT data link message could convey that a "mayday" / incident / accident was in progress or was about to happen. Data link would be LOS and if activated while airborne would have a wide area of coverage. Example: In oceanic airspace, "Lost pressurization and am deviating off assigned track, descending."

Down-link needs: The data link message needs to be received by all appropriately equipped ground stations within LOS (e.g., ATM, AFSS / FSS, ARINC, etc.) and, also, on 408 MHz by SARSAT. The data message should include GPS based position, time of occurrence, aircraft ID, and "code" to indicate what happened.

8. FSS specialist display to assist in providing in-flight weather update briefings and in "DF" (i.e., ADS-B based) pilot steers.

Up-link needs: None

Cross-link needs: None

Down-link needs: The AFSS can use ADS-B to assist the EFAS position specialist and FSS specialist in performing their assigned duties. This would be a "passive" monitoring function.

9. Reduced controller workload by electronically transmitting of pre-departure VFR and IFR clearances in textual / graphical format along with data to support a cockpit presentation of digitized textual / graphical ATIS.

Up-link needs: ATM needs to be able to send this data in a suitable format to the aircraft. The SAS computer needs to be able to display the data received in both textual and graphical format, depending on the specific type of information being sent, and whether it lends itself to a textual or graphical presentation format.

Cross-link needs: None

Down-link needs: The aircraft needs to acknowledge receipt of this data link message and to reject those that are unacceptable or to challenge those that are not well understood.

10. Down linking of requests for alternate airport flight plans direct to the appropriate controller due to weather and other in-flight diversions.

Up-link needs: ATM needs to process these priority aircraft data link messages and assign an amended clearance ASAP.

Cross-link needs: None

Down-link needs: The pilot, using his SAS display, would compose and send a request for an amended clearance via data link. This request could be done beforehand and automatically initiated by something as simple as the execution of a rejected landing procedure or from an aborted approach upon reaching minimums.

11. Improved / enhanced flight following. Reduced air traffic workload by using real-time / stored ADS-B data in lieu of manually searching for an aircraft when a pilot fails to close-out a flight plan in a timely manner.

Up-link needs: None.

Cross-link needs: None

Down-link needs: No specific action required. ADS-B information would be searched by air traffic for any evidence of the aircraft by either its assigned ICAO assigned ID or "N" number.

12. Progressive taxi instructions enhancement -- Use of ADS-B to assist the controller in locating aircraft on the airport surface, especially on initial call-up or while in a string of aircraft awaiting take-off clearance.

Up-link needs: None.

Cross-link needs: None

Down-link needs: The ADS-B message would be sent to air traffic control and the aircraft's position displayed in the tower cab.

13. ADIZ penetration and other special use ADS-B messages to NORAD or to other appropriate federal / state organizations.

Up-link needs: None.

Cross-link needs: TBD

Down-link needs: The standard ADS-B message would be received by air traffic and electronically provided to the appropriate requesting authority. It may also be desirable to include other information, i.e., passengers, point of embarkation, etc., in an accompanying data link message. Specific data link requirements would need to be coordinated with the potential users of the data.

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APPENDIX 10: LIST OF ACRONYMS

AAF -- FAA's Airways Facilities Division

AAI -- FAA's Office of Accident Investigation

AAM -- FAA's Office of Aviation Medicine

ABB -- FAA's Office of Budget

AC -- Advisory Circular

ADS-B -- Automatic Dependent Surveillance -- Broadcast

ADF -- Aircraft Dispatchers Federation

ADIZ -- Air Defense Identification Zone

AF -- FAA's Office of Airway Facilities

AFFSA -- Air Force Flight Standards Agency

AFM -- Airplane Flight Manual

AFS -- FAA's Flight Standards

AFSS / FSS -- Automated Flight Service Station / Flight Service Station

AGATE -- NASA's Advanced General Aviation Transport Experiment

AGI -- FAA's Office of Government and Industry Affairs

AGL -- Above Ground Level

AHS -- American Helicopter Society

AIA -- FAA's International Aviation Office

AIR -- FAA's Office of Aircraft Certification

ALPA -- Airline Pilot's Association

AMSS -- Air Mobile Satellite Service

AND -- FAA's Office of Communications, Navigation, and Surveillance

ANE -- FAA's New England Region

ANM -- FAA's Northwest Mountain Region

AOC -- Aeronautical Operational Control; also, Airline Operations Center.

AOPA -- Aircraft Owners and Pilot's Association

AOPA/ASF -- AOPA - Air Safety Foundation

APA -- Air Pilot's Association

API -- FAA's Office of Policy, Planning, and International Aviation

ARINC -- Aeronautical Radio, Inc.

ARM -- FAA's Office of Rule Making

ARP -- FAA's Rocky Mountain Region

ARPA -- The Department of Defense Advanced Research Projects Agency

ASAP -- As Soon As Possible

ASC -- FAA's Office of Systems Capacity

ASE -- FAA's Office of Systems Engineering

ASTA -- Airport Surface Traffic Automation.

AT -- FAA's Air Traffic Services

ATA -- Air Transport Association

ATC -- Air Traffic Control.

ATM -- Air Traffic Management

ATIS -- Automatic Terminal Information Service.

ATM -- FAA's Air Traffic Management.

ATP -- FAA's Office of Air Traffic Control Procedures

ATP -- FAA's Air Traffic Procedures Division

ATZ -- FAA's Office of Air Traffic Management

AVN -- FAA's Office of Aviation System Standards

AWOS / ASOS -- Automated Weather Observing System / Automated Surface Observing System

CAMI -- FAA's Civil Aviation Medicine Institute

CBI -- Computer Based Instruction

CD/U -- Computer conventional keyboard

CFIT -- Controlled Flight into Terrain.

CFR -- Consolidated Federal Regulations

CIP -- Capital Investment Plan.

CNS -- Communications, Navigation, Surveillance

CTAS -- Center - TRACON Automation System

DF -- Direction finder / direction finding equipment.

DLORT -- Datalink Operational Requirements Team

DMA -- Defense Mapping Agency.

DME -- Distance Measuring Equipment

DNL -- Day / night sound level; "DNL" is a cumulative measurement of noise.

DOD -- Department of Defense

DOD-ARPA -- DOD - Advanced Research Programs Agency

DOD-DMA -- DOD - Defense Mapping Agency

DOI-BLM -- Department of Interior - Bureau of Land Management

DOT -- Department of Transportation

DOTS -- Dynamic Ocean Track System

DTED / DVOD -- Digital Terrain Elevation Data and Digital Vertical Obstruction Data. Both data bases are part of a "3D" terrain data base that would support a second generation CFIT system.

EAA -- Experimental Aircraft Association

EFAS -- En Route Flight Advisory Service

EHSI -- Electronic Horizontal Situation Indicator

ELS --- Electronic Library System. ELS is basically a data management file stored on an aircraft.

ELT --- Emergency Location Transmitter. The ELT sends signals to the ground receivers, other aircraft, and to search and rescue satellites.

FandE -- Facilities and Equipment

FAA -- Federal Aviation Administration

FANG -- "FMS - ATM, The Next Generation". "FANG" and SAS are the two major activities being pursued within the context of the FTMI mission need statement.

FAR -- Federal Aviation Regulations

FMS -- Flight Management System. FMSs handle a variety of critical functions in addition to basic navigation management. An FMS can control weather radar, tune the radios, direct steering commands to the flight control system (called the "autopilot" function), and also provides diagnostics control for the aircraft's engines and avionics suite.

FNS -- Flight Navigator System. An FNS is a lower cost GPS-based flight navigator with less functionalities than its FMS counterpart.

FOQAP -- Flight Operations Quality Assurance Program

FSF -- Flight Safety Foundation

FTMI -- Flight Operations and Air Traffic Management Integration.

FYI -- "For Your Information"

GA -- General Aviation

GB -- Gigabytes

GAMA -- General Aviation Manufacturing Association

GARSD -- General Aviation Research Simulation Device

GEO -- Geosynchronous Earth Orbit

GOES -- Geopsynchronous Observation of Earth Satellite

GPS -- NAVSTAR Global Positioning System.

GUI -- Graphical User Interface

HAI -- Helicopter Association International

HF -- High Frequency

IACC -- Interagency Air Cartographic Committee

ICAO - International Civil Aviation Organization

ID -- Identification

IFR -- Instrument Flight Rules.

ILS -- Instrument Landing System

I / O -- Input / Output device.

IPT -- Integrated Product Team.

IR -- Military low-level Instrument Routes

ISASI --

ITWS -- Integrated Terminal Weather System.

Kbps -- Kilobytes per second

LAAS -- Local Area Augmentation System

LAHSO -- Land and Hold Short Operations

LEO -- Low Earth Orbit

LORAN -- Long Range Navigation

LOS -- Line-of-sight

TPA -- Traffic Pattern Altitude

MAP -- Missed Approach Point

MEO -- Medium Earth Orbit

MFD -- Multi-function Display.

MNS -- Mission Need Statement.

MOA -- Memorandum of Agreement.

MTR -- Military Training Routes

MVA -- Minimum Vectoring Altitude

NAATS -- National Association of Air Traffic Specialists

NAS -- National Airspace System

NASA -- National Aeronautics and Space Administration

NATA -- National Air Traffic Association

NATCA -- National Air Traffic Controllers Association

NBAA -- National Business Aircraft Association

NDB -- Non Directional Beacon

NOAA -- National Oceanographic and Atmospheric Agency

NOTAMS -- Notices to Airmen.

NTSB -- National Transportation Safety Board

OAT -- Outside Air Temperature.

OROCA -- Off-Route Obstruction Clearance Altitude. OROCA is ELS derived data obtained from an electronically generated combined moving map and "2D" terrain data base.

OTS -- Out of Service

PandL -- Parts and Labor

PC -- Personal Computer

PCMCIA -- Personal Computer Memory Card International Association. PCMCIA cards are credit-card size adapter cards that add memory, storage, and I/O capabilities to portable and installed systems.

PDM -- Pilot Decision Making

PIC --- Pilot-in-command.

PIREPS -- In-flight pilot weather reports. PIREPS can be either manually or automatically provided to air traffic or, by voice, to the nearest Flight Service Station or NWS facility.

PRM -- Precision Runway Monitoring.

PnP -- "Plug and Play". PnP is an emerging standard for PC-based hardware and software.

POC -- Point-of-Contact

RA -- TCAS Resolution Advisory.

RAA -- Regional Airline Association

REandD -- Research, Engineering, and Development

RNP -- Required Navigation Performance

RTCA -- RTCA, Inc.

SAE -- Society of Automotive Engineers

SAMA -- Small Aircraft Manufacturers Association

SARPs -- ICAO Standards and Recommended Procedures

SAS -- Situational Awareness for Safety. Pilots need to have situational awareness with themselves (i.e., "P" for pilot), with their aircraft (i.e., "A" for aircraft), and their operating environment (i.e., "E" for their external environment).

SARSAT -- Search and Rescue Satellite. The Russian orbital satellite equivalent of the U.S. SARSAT is called COSPAS

SC -- RTCA Special Committee

SMGCS -- Surface Movement Guidance and Control System.

SRT -- System Requirements Team

SSR -- Secondary Surveillance Radars

SUA -- Special Use Airspace

TA -- TCAS Traffic Advisories

TCAS -- Traffic Collision Avoidance System.

TCH -- Threshold Crossing Height

TCP -- Tactical Conflict Probe. This would be a functional capability which would provide on-board surveillance capability thus enabling "free flight".

TDMA -- Time Division Multiple Access

TDWR -- Terminal Doppler Weather Radar.

TPA -- Traffic Pattern Altitude

TSD -- Traffic Situation Display.

UHF -- Ultra High Frequency

USAF -- United States Air Force

USAF-FDL -- USAF - Flight Dynamics Laboratory

USAF-OSR -- USAF - Operational Systems Research

USGS -- United States Geological Society

USAASA -- United States Army Aeronautical Services Agency

VDL -- VHF Digital Data Link

VFR -- Visual Flight Rules.

VHF -- Very High Frequency.

VIP -- Video Image Processing; "VIP" is a measurement of the intensity of radar returns

VMC -- Visual Meteorological Conditions

VOR -- VHF Omnidirectional Range

VR -- Military Low-level Visual Routes

VSI -- Vertical Speed Indicator

VRE -- Voice Recognition Equipment

WAAS -- Wide Area Augmentation System

WG -- Working Group